AMRA MS 65-09

A REPORT GUIDE TO ULTRASONIC ATTENUATION LITERATURE

MONOGRAPH SERIES

by

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DECEMBER 1965

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PREFACE

This journal was prepared by the U. S. Army Materials Research Agency (AMRA) and all information contained herein was taken from the Nondestructive Testing Information Retrieval System.* All items included cover some aspect of Ultrasonic Attenuation even though the majority include numerous other descriptors. Each item is covered by as many descriptors as was deemed necessary for complete coverage of that item.

The intent of this journal is to assist research investigators and industrial inspection personnel by providing a ready reference and access to the extensive and widely scattered literature on the subject matter.

The information contained in the Nondestructive Testing Information Retrieval System has been obtained from numerous sources such as the Defense Documentation Center; NASA; Engineering Index; foreign translations; numerous books; technical journals, etc. Many of the items listed were taken directly from complete reports currently on file at AMRA, while others may have been taken directly from abstract cards on the subject matter supplied by DDC, World Information Files, etc.

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Henry Brutcher Technical Translations,** Altadena, California

Materials Evaluation (formerly Journal of Nondestructive Testing), Evanston, Illinois

Ultrasonics, Illife Publications Ltd., London, England

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*JOHNSON, P. W., and MERHIB, C. P. The Nondestructive Testing Information System. U. S. Army Materials Research Agency Monograph Series, AMRA MS 64-02, March 1964.

**In the abstracts, Henry Brutcher Technical Translations are identified by the initials HB.

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INTRODUCTION

Where available, each item in this journal consists of the following information: (1) item report, or article title, (2) author or authors, (3) source or facility, (4) report number or identification, (5) date, and (6) abstract.

Word descriptors pertinent to each item are listed in alphabetical order and are cross-referenced by the AMRA identification number. Also provided is an author index or, if no author is available, then the issuing organization is listed.

OBJECTIVE

The main objective of this compilation is to provide a simple and fast access to information on the subject of Ultrasonic Attenuation, and also to provide sufficient information in the form of abstracts and word descriptors to make the listing useful.

SCOPE

This guide consists of a bibliography of items currently in the AMRA Nondestructive Testing Information Retrieval System covering the subject of Ultrasonic Attenuation. It is realized that there are many items, both foreign and domestic, that may not be included; however, it is believed that sufficient information is available to make this guide extremely useful and time saving to those interested.

If sufficient interest is noted from comments to this guide, additional guides will be prepared on other methods in the field of nondestructive testing.

Supplements to Ultrasonic Attenuation literature will be prepared as the system grows and sufficient data is available.

SOURCES

The information contained herein and in the AMRA Nondestructive Testing Information Retrieval System has been gathered from many sources such as the Defense Documentation Center, World Information Files, Engineering Index, foreign translations, numerous books, technical journals, and Department of Defense installation reports.

USAGE

All word descriptors included in this guide are listed in alphabetical order and are cross-referenced to the AMRA report identification number. Also listed is an author index, or, if no author name is available, then the issuing organization is listed. Users have only to refer to those descriptors that they are concerned with at the time and read only those abstracts which the descriptors cross-reference.

The abstracts normally refer the reader to the source where the complete report may be obtained if the reviewer desires to do so.

ABSTRACTS

AMRA
IDENTIFICATION
NUMBER

4 DETERMINATION OF THE CAUSE OF FAILURE AND NONDESTRUCTIVE TECHNIQUES FOR SEGREGATING REJECTABLE 20MM M39 MACHINE GUN BARRELS
E. H. Rodgers, J. M. Ingraham, E. L. Reed and J. W. Orner
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 761.5/1, September 1959, 15 p.

Evaluation of the mechanical and metallurgical properties of ruptured 20MM M39 machine gun barrels confirmed the brittle nature of the fractures and the inadequacy of the applicable machine gun barrel specification for the procurement of clean, tough steel. Nondestructive tests were developed utilizing the magnetic properties and the ultrasonic attenuation characteristics of the material whereby barrels having undesirable microstructures (and therefore low impact values) could be easily detected.

8 SPECTRUM AND CONTOUR ANALYSIS OF ULTRASONIC PULSES FOR IMPROVED NONDESTRUCTIVE TESTING
O. R. Gericke
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 830.5/1, December 1960, 19 p.

A novel technique for obtaining the ultrasonic attenuation/frequency relationship in a single operation is suggested and investigated. This new method employs ultrasonic pulses which contain energy over a wide band of frequencies, and uses a spectrum analyzer to detect the frequency dependence of ultrasonic attenuation.

13 ULTRASONIC ATTENUATION IN SAE 3140 AND 4150 STEEL
E. P. Papadakis
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 143/31, April 1959, 23 p.

The attenuation of longitudinal ultrasonic waves is studied by the pulse technique in blocks of SAE 3140 and 4150 steel to determine the loss mechanism and to find possible methods for precision testing the microstructure of materials. It is found that scattering by the grains in the polycrystalline steel is responsible for the attenuation in tempered steel. The critical quantities are the grain diameter and the average squared fractional variation in the elastic modulus of a single grain. The value of the average squared fractional variation in the elastic modulus in bainite seems to be larger than in martensite or ferrite. Methods of materials testing to investigate grain size and grain quality are outlined.

14 DETECTION BY NONDESTRUCTIVE TESTS OF OVERHEATING IN 2014-T6 ALUMINUM ALLOY

P. C. McEleney and E. L. Reed AD 238270
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 140/27, May 1960, 45 p.

Ultrasonic attenuation tests have proved to be successful in the detection of "overheating" or "burning" in 2014-T6 aluminum alloy. Heretofore overheating was detected only by metallographic examination. Correlation between ultrasonic attenuation tests and metallographic studies of a series of overheated and non-overheated 2014-T6 aluminum alloy samples has been successfully accomplished. Liquid penetrant, radiographic and electromagnetic tests can also be applied in certain instances to detect this condition.

15 ULTRASONIC DOUBLE REFRACTION IN 4150 STEEL

P. F. Sullivan
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 143/38, June 1961, 9 p.

In this work the double refraction observed while measuring the attenuation of ultrasonic transverse waves in heat-treated 4150 steel was investigated. Although the data are not complete, it is suggested this double-refraction phenomena can be utilized to detect the amount of preferred orientation of the crystallites in rolled steel when this orientation is small. Calculated values of fractional velocity differences are given.

16 ULTRASONIC ATTENUATION AND PHYSICAL PROPERTIES OF METALS

J. W. Orner AD 609897
U. S. Army Materials Research Agency, Watertown, Mass.
Watertown Arsenal Labs MS-20, November 1960, 11 p. w/illus.

The relation of ultrasonic attenuation in a solid to the large number of intrinsic variables involved is qualitatively discussed. Some of the variables are: Frequency, strain, temperature, strain cycling, fatigue, grain size and orientation, and radiation damage. Practical solutions to the problem of heat treatment of gun barrels and aluminum are described.

86 MANUAL FOR ULTRASONIC ATTENUATION UNIT
WAL M-1, July 1961, 31 p. w/illus., U. S. Army Materials Research Agency, Watertown, Mass.

Information on the application of ultrasonic attenuation and velocity in solids, is presented. Such topics are considered as construction, operation and calibration of equipment, correction of data obtained by means of the equipment, and such general topics as preparation of samples, transducers and coupling.

87 DETERMINATION OF FLAW GEOMETRY BY ULTRASONIC PULSE CONTOUR AND SPECTRUM ANALYSIS
J. J. Maguire
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 830.5/2, July 1961, 14 p.

This report describes the application of ultrasonic pulses of almost rectangular envelope to pulse-echo testing, resulting in the simultaneous transmission of a wide band of ultrasonic frequencies. In comparison to the essentially monochromatic ultrasound used in conventional test systems, this method permits the derivation of additional information from the test, obtained in the form of the spectral energy distribution after reflection from the defect. Besides determining the location of a flaw, it is now possible to gather data representing the flaw geometry.

92 ULTRASONIC POLE PATTERNS
E. P. Papadakis
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TN 143/39, July 1961, 7 p.

The theory of ultrasonic wave propagation in polycrystalline metal is discussed and the effect of preferential orientation of crystallites on fractional velocity changes is indicated. The use of ultrasonic double refractional data for determining extent of preferential orientation is suggested.

93 THE GRAIN SIZE DISTRIBUTION IN METALS AND ITS INFLUENCE ON ULTRASONIC ATTENUATION MEASUREMENTS
E. P. Papadakis
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 830.4/1, February 1961, 18 p.

A transformation (derived by relating the number of spheres of a certain radius per unit volume to the number of circles smaller than a certain radius per unit area appearing on a plane cutting through the volume) was applied to several hypothetical grain size distributions for polycrystalline metals to find the resulting hypothetical area distribution of grain images on photomicrographs. Comparison of the hypothetical to the experimentally found area distribution gave certain conditions that the true volume distribution of grains must meet. A correlation was computed for the attenuation formulas for Rayleigh scattering of ultrasonic waves in polycrystalline metals by taking averages over certain functions which were judged plausible for the volume distribution of grains.

95 THE INTERACTION OF ELECTRONS WITH ELASTIC WAVES IN SOLIDS WITH RESPECT TO ULTRASONIC ATTENUATION
E. P. Papadakis
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 143/32, May 1960, 30 p.

Theoretical and experimental work by many researchers shows that the attenuation of ultrasonic elastic waves in metals at liquid helium temperatures is dependent upon the momentum transfer between the electrons and the lattice, the population of electrons in the normal and superconducting states, and the orientation of the elastic displacement with respect to an applied magnetic field. The work is summarized and the results presented in equations and graphs.

122 USE OF ULSTRASOUND FOR STUDY OF THE STRUCTURE OF STEELS
L. G. Merkulov
HB 4057, Zhurnal Tekhnicheskoi Fiziki, Vol. 27, No. 6, 1957, p. 1387-1391

Application of ultrasonics (frequency to 60 mc) attenuation of longitudinal waves as a measure of grain size and structural state is reported. Attenuation by scattering and damping is considered; the former is related to grain size determination and the latter to the determination of structural state produced by heat treatment. Medium carbon structural steel, 1.2 carbon tool steel and chrome-nickel alloy steel were investigated.

147 ULTRASONICS IN THE STUDY OF HIGH TEMPERATURE BEHAVIOR OF MATERIALS
R. Truell
Proc. of Bureau of Naval Weapons, Missiles, and Rockets Symposium, Concord, California, 1961, p. 264-265

Ultrasonic measurements are closely related to the compressibility, strain energy, and the elastic moduli. Measurements can show changes in these fundamental properties of material with temperature and transitions, and thus give information about bonding forces, cohesive energies, thermal expansion, specific heat, density, and details of the structure and behavior of dislocations.

162 QUALITY INSPECTION OF MATERIALS BY ULTRASONIC METHODS IN JAPAN
T. Hirone, Tokyo University
Proc. of the Third International Conf. on NDT
Tokyo, 1960, p. 317-324, Pan-Pacific Press, Toyko, 1961

This article describes investigations conducted in Japan on the method of measuring ultrasonic attenuation and its relationship between attenuation and internal stress or creep deformation. It points out that ultrasonic velocity and attenuation coefficients in metals are influenced remarkably by the heat treatment or by their macro or microstructures. Ultrasonic attenuation characteristics are greatly influenced by the quenching and annealing of steel. A bibliography of papers covering this type of work conducted in Japan is included.

167 THE USE OF ULTRASONIC METHODS FOR THE EXAMINATION OF FATIGUE EFFECTS IN METALS DURING THE EARLY STAGES OF STRESS CYCLING
R. Truell, et al
Metals Research Laboratory, Brown University, Providence, R. I.
WADD TR 60-920, December 1960, 28 p.

Ultrasonic methods for studying defect formation and its consequences in connection with stress cycling and fatigue of aluminum are discussed. The measurement of changes of ultrasonic attenuation and velocity during stress cycling are shown together with the accompanying changes in the metallographic character of the surface sample as determined by acetate replicas and optical methods as well as oxide replicas and electron micrographs. The creation and improvement for the automatic recording of attenuation and velocity changes has been a major part of the effort thus far, and a discussion of this equipment appears here.

181 THE STUDY CONCERNING THE RELATION BETWEEN THE TRANSMISSION SPEED OR THE ATTENUATION DEGREE OF ULTRASONIC AND THE DEGREE OF GRAPHITIZATION
K. Kanazawa and Y. Ueda
Proc. of the Third International Conf. on NDT
Tokyo, 1960, p. 636-641, Pan-Pacific Press, Tokyo, 1961

This article describes studies conducted with relation to the transmission speed or the attenuation degree of ultrasonics and degree of graphitization about the specimens which were graphitized by annealing at temperatures between 650°-670°C after quenching or welding. Ultrasonic attenuation comparators and synchroscopes were utilized in the studies. The authors state that the transmission speeds of ultrasonics decreased three to five percent, and the attenuation degree of ultrasonics rapidly increased to four or five times when the degree of graphitization in the specimen matrix grew severe as compared to slight graphitization or none at all.

182 ULTRASONIC FLAW INSPECTION OF METALS AT HIGH TEMPERATURES
T. Hirone and K. Kamigaki, Tokyo University
Proc. of the Third International Conf. on NDT
Tokyo, 1960, p. 631-635, Pan-Pacific Press, Tokyo, 1961

An extensive investigation of the use of ultrasonic flaw inspection methods at high temperature ranges is discussed in this article. These investigations cover ultrasonic attenuation and velocity measurements, flaw detection at both high and room temperatures and the results compared with X-ray techniques. Confirmation of the results show that the distribution of flaws detected by ultrasonic methods at high temperatures coincide with those taken at room temperature and correlate well with radiography.

189 NONDESTRUCTIVE TESTING OF REACTOR FUEL ELEMENTS AT HANFORD
R. S. Paul, General Electric Co., Hanford Works
Proc. of the Third International Conf. on NDT
Tokyo, 1960, p. 423-428, Pan-Pacific Press, Tokyo, 1961

This paper describes the continuing research program underway at Hanford in an attempt to find new test methods, to improve the sensitivity and reliability of present tests, and to automate for high volume testing. Ultrasonic attenuation methods used to test for proper grain size is explained as well as sonic resonance vibration test for grain orientation investigations. Both ultrasonic and eddy current flaw detection techniques are discussed. Advanced research currently in progress in the fields of broadband or multi frequency eddy current testing as well as new ideas in ultrasonic testing and infrared methods of measuring heat transfer characteristics is outlined.

193 ATTENUATION AND VELOCITY MEASUREMENTS IN 1013 STEEL AS A FUNCTION OF DEFORMATION AND HEAT TREATMENT
A. Hikata and R. Truell
Brown University, Providence, R. I.
WAL 143/20-48, January 1958, 11 p. w/graphs

Ultrasonic attenuation and velocity measurements were made in 1013 steel while the steel was being deformed. A rather strange attenuation-strain behavior results. This behavior apparently is not caused by dislocation damping changes or scattering but preliminary results support the contention that this is at least in part a magnetic phenomenon. It is also shown that the attenuation-strain behavior is sensitive to the heat treatment to which the sample has been subjected.

221 INVESTIGATION OF RESIDUAL STRESS IN FERROMAGNETICS USING ULTRASONICS
W. J. Bratina and D. Mills
SNT Journal, March-April 1960, p. 110-113

Ultrasonic attenuation characteristics are used to study the residual stresses in low carbon steels. The presence of a residual stress is shown to be indicated by a characteristic maximum in the ultrasonic attenuation plotted versus applied stress on magnetic field. Magnitude is related to the position of the maximums. Microstresses are mainly considered and they appear readily detectable. Further development of this method could lead to a practical means for nondestructive determination of stresses in metals.

238 EARLY DETECTION OF FATIGUE IN METAL ALLOYS BY ULTRASONICS
K. Sittel
SNT Journal, May-June 1959, p. 165-171

Solid metals readily transmit acoustic waves, but the wave energy is attenuated to some extent by various causes such as heat conduction, motion of dislocations, motion of grain boundaries, movements of atoms, and scattering. These are explained as are the means for separating attenuation caused by other effects. It is believed that the growth and movement of dislocations is actually the predominant process occurring in the early stages of fatigue damage. Hence, the damage may be found before the structural part becomes measurably weakened. Present acoustical methods are described and their application to fatigue studies are given. Effects which occur in the fatigue life of a specimen are described. The circumstances under which these phenomena may be observed ultrasonically are pointed out. The choice of a test sample for fundamental study is discussed, and some suggestions are made for routine testing.

292 ULTRASONIC ATTENUATION AND VELOCITY IN SAE 4150 STEEL
E. P. Papadakis et al
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TR 143/37, December 1961, 88 p. w/graphs

Ultrasonic attenuation and velocity measurements have been made on SAE 4150 steel in the hot-rolled, austenitized-and-quenched, and tempered conditions to study temper embrittlement. It was found that the ultrasonic measurements did not show any correlation with the hardness or the notched-bar breaking energy of the steel. The attenuation from both elastic hysteresis and Rayleigh scattering decreased on quenching and also on tempering. The reduction of residual stresses lowered the elastic hysteresis. The decrease in Rayleigh scattering was caused partially on quenching and entirely on tempering by reductions in the elastic anisotrophy of the contents of the prior austenite grain volume. Ultrasonic double refraction was observed during transverse wave measurements on the tempered specimens.

385 AN ULTRASONIC ATTENUATION MEASURING EQUIPMENT
G. A. Darcy, Jr. and W. J. Curry
U. S. Army Materials Research Agency, Watertown, Mass.
WAL 143/25, 1 November 1952

An ultrasonic attenuation measuring equipment for use on steel has been designed and constructed. This equipment is being employed to investigate the possibility of supplanting certain destructive tests with nondestructive ultrasonic tests. The device has a frequency coverage of 5 to 30 megacycles and an input sensitivity of 2.5 microvolts.

484 ATTENUATION OF 5 MC SOUND IN ALUMINUM AT LOW TEMPERATURES
T. S. Hutchison and A. J. Filmer
Royal Military College, Kingston, Canada
Reprint, Canadian Journal of Physics, 1956

It has been found that the attenuation of sound reaches a maximum when using a frequency of 5 megacycles at 155°K in aluminum. Plastic deformation greatly increases the maximum. The maximum difference in the velocity of sound for cold-worked and annealed aluminum appears at 155°K which indicates dislocation mechanism.

506 ATTENUATION OF ULTRASOUND IN TUNGSTEN CARBIDE POWDER MIXTURES AT MEGACYCLE FREQUENCIES
R. L. Roderick and R. Truell
Brown University, Providence, R. I.
WA Contract DA-19-020 ORD 48, 1951

The attenuation of longitudinal ultrasound in the frequency range from 10 to 30 mc was measured in two tungsten carbide powder mixtures of different average grain sizes using the pulse technique and a water buffer. The larger grain size specimen had larger attenuation coefficients. Both Rayleigh scattering and true absorption appear to be inadequate to explain the attenuation observed. A method is suggested for detecting "flaws" which are not pronounced enough to actually reflect the sound pulses. A more extensive sampling is necessary before a good empirical law can be formulated.

551 ULTRASONICS AND THE PHYSICS OF SOLIDS
R. Truell
Brown University, Providence, R. I.

A survey will be given of some of the uses of ultrasonic attenuation and velocity measurements in the study of the properties of solid materials. An outline will be given of the relative importance of scattering and dislocation damping in various applications to the study of the "quality" of materials. Deformation, fatigue, and radiation effects will be discussed to the extent that time permits.

554 PRELIMINARY ATTENUATION DATA WITH STEEL SAMPLES OF DIFFERENT HARDNESS
R. L. Roderick and R. Truell
Brown University, Providence, R. I., Contract DA-19-020-ORD-13, 1950
WAL 143-14-7

This article cites preliminary Attenuation Data with Steel Samples (37MM A. P. Shot) of different Hardness. It has been found that the boundary measurements do have an important effect on the measurements independent of the material. Further work is necessary.

556 ULTRASONIC ATTENUATION IN THE STUDY OF ELASTIC AND PLASTIC DEFORMATION BEHAVIOR ESPECIALLY IN ALUMINUM
A. Hikata, R. Truell, A. Granato, B. Chick and K. Lucke
Brown University, Providence, R. I., Contract DA-19-020-ORD-1579,1955
WAL 143/14-45

Interesting effects have been observed in the course of comparing measurements of ultrasonic attenuation at megacycle frequencies as a function of strain with load-strain measurements made on the same tensile test specimen at the same time The results show clearly the sensitivity of ultrasonic attenuation to the fine details of the mechanisms involved in elastic and plastic deformation.

557 ULTRASONIC ATTENUATION IN CRYSTALS DUE TO THE THERMOELASTIC EFFECT
K. Lucke
Brown University, Providence, R. I., Contract DA-19-020-ORD-1579,1956
WAL 143/14-46

The thermoelastic attenuation for sound waves has been computed for single crystals and polycrystalline materials under application of the high frequency approximation of sound propagation. For single crystals the attenuation in the main propagation directions have been computed explicitly for cubic and hexagonal crystals taking into account the anistrophy of the elastic properties and thermal expansion.

558 MULTIPLE SCATTERING OF WAVES
P. C. Waterman and R. Truell
Brown University, Providence, R. I., Contract Nos. DA-19-020-505-ORD-3882 and 3650, 1957
WAL 143/14-49

Governing equations are obtained for the problem of multiple scattering of waves in a homogeneous isotropic medium containing a statistical array of scattering regions. The equations are applicable to sound waves in solids, liquids and gases, electromagnetic waves, and stationary quantum-mechanical problems. From these equations the macroscopic properties of the scattering medium may be obtained in terms of the scattering properties of a single scatterer. Questions of energy and measurement are discussed, and several examples are considered. An extension of the theory to the elastic problem with mode conversion is included.

559 THE DETECTION OF INTERMEDIATE AND SMALL FLAWS IN SOLID MATERIALS
D. H. Evans and R. Truell
Brown University, Providence, R. I., Contract Nos. DA-19-020-ORD-1579, 1953
WAL 143/14-42

Using ultrasonic attenuation methods in solid materials it has been found that flaws which cannot be detected by conventional echo methods are nevertheless detectable by observation of certain behavior of the pulse attenuation pattern. The deviation of the pulse amplitude decay from exponential form is, under proper circunstances, evidence of intermediate or small flaws.

560 ULTRASONIC ATTENUATION OF A TEMPER EMBRITTLED STEEL
D. H. Evans and R. Truell
Brown University, Providence, R. I., Contract No. DA-19-020-ORD-817, 1953
WAL 143/14-33

Temper brittlement in SAE 4150 steel has been partially investigated by ultrasonic attenuation techniques. It has been found that the attenuation is related to the breaking energy, as given by the Charpy impact test, and to hardness. The relationship found appears to be complex in nature; the attenuation-hardness curves show sharp maxima for certain values of the hardness and of the breaking energy if the sample is tough and for other values of hardness and breaking energy if the sample is brittle.

561 DIFFRACTION EFFECTS IN THE ULTRASONIC FIELD OF A PISTON SOURCE AND THEIR IMPORTANCE IN THE ACCURATE MEASUREMENT OF ATTENUATION
H. Seki, A. Granato and R. Truell
Brown University, Providence, R. I., Contract No. DA-19-020-ORD-1579, 1954
WAL 143/14-44

A study is made of the ultrasonic field produced by a circular quartz crystal transducer and the integrated response of a quartz crystal receiver with the same dimensions as the transducer. The transducer and receiver are taken to be coaxial, and it is assumed that the transducer behaves as a piston source while the integrated response is proportional to the average pressure over the receiving area. Computations are made for cases of interest in the megacycle frequency range (Ka = 50 to 1000). The results contain features of use in identifying and correcting for diffraction errors. These features which apparently have been missed in previous investigations are compared with available experimental data. Finally, correction formulas to account for diffraction effects in the accurate measurement of attenuation are discussed.

562 NEUTRON IRRADIATION EFFECTS IN BOROSILICATE GLASS AND THEIR DETECTION BY ULTRASONIC AND BIREFRINGENCE MEASUREMENTS
R. Truell, J. de Klerk and C. Mylonas
Brown University, Providence, R. I., Contract No. AF 33 (616) - 3019, 1957

This report summarizes the work done in studying the effect of the reactions of slow neutrons with boron in glass. The resultant damage or radiation effects were detected and examined by two methods: (1) By photoelastic study of the stress pattern resulting from radiation induced strains in the glass. The ultrasonic method showed the expected attenuation increase with irradiation but also an unexpected reversal of the velocity-frequency behavior as compared to that observed before irradiation. The photoelastic method showed that the strains induced by the neutron-B^{10} reactions vary with the depth from the glass surface in direct proportion to the neutron flux, and that they can therefore be used for direct irradiation measurements. Accordingly this report is divided into two parts corresponding to the two methods used to study the radiation effects.

563 THE TEMPERATURE DEPENDENCE OF THE ATTENUATION OF ULTRASOUND IN A NICKEL SINGLE CRYSTAL
F. West
Brown University, Providence, R. I., Contract No. DA-19-020-ORD-3650, 1957
Office of Ordnance Research

Attenuation in the Magnetically Saturated State: From the measurements of the attenuation as a function of frequency it can be concluded that the energy loss in the saturated state is the result of a relaxation loss mechanism. It is found that the relaxation frequency is not measurably temperature dependent; however, the shape of the relaxation curve depends on the history of the specimen. The nature of the loss mechanism is not known, but it is probably related to the dependence of the velocity of an ultrasonic wave on the orientation of the saturation magnetization which has been observed by other workers.

564 FATIGUE IN 2S ALUMINUM AS OBSERVED BY ULTRASONIC METHODS
R. Truell and A. Hikata
Brown University, Providence, R. I., Contract Nos. DA-19-020-505-ORD-3882 and 2598
WAL 143/14-47

One of the most important results of this experiment is the fact that at the beginning of the experiment the material had a large recovery effect, and at the end of ten million cycles there was no detectable recovery effect. In other words initially the material was statically loaded and, while held at constant load, the attenuation would decrease to the initial value. At the conclusion of the fatigue cycling the attenuation did not change. Loading to the same load used in the experiment did not increase the attenuation and while standing at constant strain, there was no measurable decrease in attenuation - the recovery effect was no longer present.

566 ULTRASONIC ATTENUATION IN METALS AT LOW TEMPERATURES
D. H. Filson
University of California, Los Angeles, Cal.
Tech. Rpt. No. XIII, January 1959

Whenever mechanical waves are generated in a solid, some of the elastic energy is always converted into heat. The mechanism by which this energy loss occurs will depend upon the characteristics of the wave generated and upon the properties of the solid medium. Several theories were rapidly advanced to explain the effect in the normal conducting state. All apparently led to the same result; that the attenuation of shear or longitudinal waves at low frequencies varies directly with the square of the frequency and with the electronic mean free path for wavelengths greater than the mean free path. The purpose of the present study is to examine more closely the attenuation of ultrasonic waves due to the electron lattice interaction.

568 ULTRASONIC ATTENUATION AND VELOCITY MEASUREMENTS IN SOLIDS
R. Truell
Brown University, Providence, R. I., Final Report, Contract No. DA-19-020-505-ORO-3882, 1959
WAL 143/14-50, Copy No. 8

This report consists of an outline which might form the basis of a book on the subject of "Ultrasonic Attenuation and Velocity Measurements in Solids." The material is written from the point of view that megacycle ultrasonic methods constitute a tool for the study of the physical properties of solid materials in the same way as do x-ray, electron, optical, and neutron diffraction methods, thermal and electrical conductivity methods, optical and mocrowave absorption measurements and so on. The material here presented is primarily the story of what physical properties can be studied by megacycle ultrasonic methods together with a discussion of the details of the methods that have been used in such investigations. As presented here, the discussion is certainly not complete in detail and in parts, the discussion is abstracted or outlined briefly. The main theme or outline is however reasonably complete.

594 MICRO-CRACK DETECTION IN STEEL FORGINGS UTILIZING ULTRASONIC ATTENUATION
R. L. Buckrop
Quality Assurance Office, Rock Island Arsenal, 1961

Ultrasonic pulse-echo equipment was used for separation of forgings with various degrees of micro-crack severity by attenuation measurements. The satisfactory material could easily be separated from the unsatisfactory. It was also possible to approximate the extent of micro-cracking in the test specimens by a percentage comparison of their back reflections to that of a standard.

609 INFLUENCE OF GRAIN STRUCTURE ON ULTRASONIC ATTENUATION IN STEEL
E. P. Papadakis
Watertown Arsenal Laboratories, Watertown, Mass.
Journal of Applied Physics, Vol. 30, No. 9, p. 1463, September 1959

This article makes a comparison between predicted and experimental values of longitudinal wave attenuation when using a frequency of 15 MC/sec with a mean grain size of ASTM6.

611 ULTRASONIC METHODS FOR NONDESTRUCTIVE EVALUATION OF CERAMIC COATINGS
W. E. Lawrie
Armour Research Foundation, Illinois Inst. of Technology, April 1961, 42 p.
WADD Tech. Rept. 61-91, Part I

This report describes investigations into the use of ultrasonics to detect defects in ceramic-metal bonds and to measure the strengths of the bonds. In the techniques investigated ultrasonic frequencies from 30 cps to 35 mc/s have been used and in one method two frequencies are used simultaneously. Low frequency energy (14 kc/s) has been sucessfully used to detect defects by decrement measurements. Low frequencies have also been used in further studies of the intermodulation method used to locate regions of bonds in which defects are present. High frequencies, up to 35 mc/s, have been used with a transmission method and visual images of defects are displayed using a simple charge scanning technique. High frequency energy has also been used in the form of surface waves. (This work is a continuation of investigations reported in WADD TR 60-157.)

613 ULTRASONIC ATTENUATION IN CAST ALUMINUM
H. Rosenthal and H. Smolen
Frankford Arsenal
Report No. R-1500, 20 p., March 1959

Since radiography does not clearly distinguish the difference between high quality aluminum castings and the ordinarily acceptable grade, there is a need for a nondestructive test method for this purpose. Aluminum test plates (7% Si-0.3% Mg) were cast with a chill on one edge and a riser at the opposite edge. It was noted that tensile properties decreased sharply when the area near the chill was compared with that near the riser. Although radiographic examination was insensitive to this change, a definite increase in ultrasonic attenuation was noted in a direction away from the chill edge. Tests made on 5% Si samples with various gas contents confirmed the observation that ultrasonic attenuation is markedly affected by the presence of gas and microshrinkage in the samples. Techniques for making ultrasonic attenuation measurements on commercial castings were not considered in this report.

617 CORRECTION FOR DIFFRACTION LOSSES IN THE ULTRASONIC FIELD OF A PISTON SOURCE
E. P. Papadakis
Watertown Arsenal Laboratories, Watertown, Mass.
Journal of the Acoustical Society of America, 1959

In pulse echo ultrasonic attenuation experiments, it is important to know the part of the measured attenuation contributed by diffraction in the ultrasonic field. In certain cases, particularly at lower megacycle frequencies in highly transmitting specimens, the diffraction loss can be much greater than the attenuation intrinsic to the specimen. The diffraction loss has been computed elsewhere as a function of the distance the ultrasonic pulse travels back and forth in the sample. Here an expression for the increment to the attenuation is derived taking into consideration at which echoes the decibel drop is measured.

656 INSTRUMENTATION FOR PULSED ULTRASONIC TESTING
J. A. Bronzo
Metals Research Laboratory, Brown University, Providence, R. I., September 1950
WAL 143/14-6

Equipment used for ultrasonic testing and attenuation measurements are described and their operation explained in detail. Block diagrams are supplied.

663 ULTRASONIC ATTENUATION IN MILD STEEL UNDER DEFORMATION
R. G. Bayer
Brown University, Providence, R. I., September 1958

The ultrasonic attenuation as a function of strain was studied for mild steel under various conditions of magnetic field and temperature. From these experiments it has been determined that the behavior of the losses in mild steel as a function of strain results from the combination of magnetic domain mechanisms and dislocation mechanisms. A heuristic model using known magnetic domain losses and known dislocation losses is proposed to explain the observed dependence.

686 INVESTIGATION OF PHYSICAL PROPERTIES OF SOLIDS BY ULTRASONIC METHODS
R. Truell AD 274827
Brown University, Providence, R. I.

This report is an outline of the work undertaken and provides a brief summary of the results. Most of the technical material has been reported in technical reports and articles. Certain properties of solid materials have been studied primarily by means of high frequency ultrasonic methods. In particular this work has been concerned with (1) study of ferromagnetic behavior in nickel single crystals at low temperatures; (2) the interaction of stress waves and electromagnetic waves in piezoelectric semiconductors such as cadmium sulphide, i.e., interaction of stress waves with charge carries; (3) phase changes in quartz and cadmium sulphide; (4) phonon-phonon interaction in insulators and semiconductors.

733 EXPERIMENTAL STUDY OF DIFFRACTION AND WAVEGUIDE EFFECTS
E. F. Carome et al, 30 November 1960 AD 248734

An experimental study has been made of the propagation of ultrasound in liquids under both free field and guided wave conditions. Free field measurements have been made from one to twenty megacycles in low absorbing liquids, employing both circular and square sound sources. These measurements indicate that the correction for diffraction loss predicted by existing theories is applicable only so long as this loss is smaller than the true absorption. Attenuation measurements also have been made in liquids confined in various cylindrical and rectangular metallic waveguides. For a given configuration, the observed variation with path length of the attenuation follows closely that predicted theoretically for propagation in a solid sample of the same dimensions. Some consideration is given to possible sources of this effect and to its importance in measurement of ultrasonic velocity.

771 CONCERNING THE PULSE METHOD OF MEASURING ULTRASONIC ATTENUATION IN SOLIDS
R. L. Roderick et al
Brown University, Providence, R. I., October 1950

The general nature of the problem under consideration discussed in this paper is that of determining experimentally the attenuation of ultrasonic waves in solid media. In particular cylindrical samples of tungsten carbide and chrome steel of predetermined diameter and lengths were examined.

782 AN ULTRASONIC ATTENUATION MEASUREMENT UNIT
B. Chick et al
Brown University, Providence, R. I.

The instrument described has been developed for the purpose of measuring ultrasonic energy losses in various materials, primarily solids, using the pulse echo method. A short duration pulse of ultrasonic energy is allowed to reflect back and forth between the parallel faces of the specimen until the echoes are no longer visible. The pulse amplitudes are presented as a function of time and echo number together with a calibrated experimental decay curve which can be fitted to the pulse echo pattern. Frequency range is from 5 mc to 200 mc; for special units 200 mc to 500 mc.

791 ON THE MEASUREMENT OF ULTRASONIC ATTENUATION IN SOLIDS AND SOME RESULTS IN STEEL
R. L. Roderick and R. Truell
Brown University, Providence, R. I., May 1951
WAL Report No. 143/14-14

Measurements in the frequency range from 5 to 50 megacycles have been made on chrome molybdenum steel specimens, and their measurements show large differences in ultrasonic attenuation for samples of the same composition but with different heat treatment. The resulting differences are not related to the austenitic grain size but they do seem to be connected with anisotropy which appears in the photomicrographs.

799 PROPAGATION OF ULTRASOUND IN FERROMAGNETIC METALS AT LOW TEMPERATURES
G. Simon
The Physical Review, Vol. 128, No. 1, 1 October 1962, p. 161

The propagation of ultrasound in ferromagnetic metals at low temperatures has been investigated utilizing the theory of cyclotron absorption of ultrasonic and microwaves. Data is presented on the force on conduction electrons in ferromagnets. Velocity and attenuation formulas of elastic waves are derived. The motion of the magnetization creates eddy currents.

800 FEASIBILITY STUDY OF DYNAMIC PROPERTIES OF PROPELLANT GRAINS
R. P. Demski
Aerojet-General Corp., Azusa, Calif.
Contract No. DA-04-495-3380, October 1962
Report No. 2328

The feasibility of using pulsed ultrasonic waves to test whole-grain live propellants was investigated. Seven propellant specimens, designated "Live Propellant for Catapult XM-10," were supplied by Picatinny Arsenal with deliberate variations imposed during fabrication. A special scanning fixture was designed and built by Aerojet to perform some of these tests. It was shown that even prolonged exposure to ultrasonic waves did not ignite live propellant with proper safety precautions. Contact ultrasonic testing using either longitudinal or shear wave techniques did not provide accurate data. Immersion tests employing mechanized scanning equipment and recording apparatus were able to detect variations in the cure cycle as well as internal flaws as small as 0.03125 in. in dia. The attenuation characteristics of each specimen were obtained by amplitude measurement of the signal response received from the back surface of the material.

810 THE USE OF SPECTRUM ANALYZER TECHNIQUES TO INVESTIGATE FACTORS AFFECTING THE MEASUREMENT OF ULTRASONIC ATTENUATION IN SOLIDS
D. H. Breslow
Brown University, Providence, R. I.
WAL TR 143/14-38, August 1956

This report is concerned with the effects of tuning, pulse width, and coupling on the attenuation measured by the direct-mount, pulse-echo method. It is shown that a spectrum analyzer may be used to determine the proper tuning, pulse width, and coupling for a specific transducer and sample and also to select a receiver of proper bandwidth for the required measurements.

1050 DETERMINATION OF THE SIZE OF DEFECTS BY THE ULTRASONIC IMPULSE ECHO METHOD
J. Krautkramer
British Journal of Applied Physics, June 1959, p. 240-245.

Calibration and standardization of ultrasonic test equipment is considered. Influence of curvature of test and back surfaces is covered. A convenient and reliable reference signal can be obtained from the first back echo. Ultrasonic attenuation of thick specimens is also covered.

1068 ULTRASONIC MEASUREMENTS ON AN UNTREATED NaCl SINGLE CRYSTAL
E. Papadakis
Massachusetts Institute of Technology, August 1959

The scope of this special problem includes the measurements able to be made by propagating ultrasonic pulses in the (100) direction in a Sodium Chloride single crystal. The velocity of longitudinal waves in this direction determines the elastic constant C_{11} while the velocity of transverse waves determines C_{44}. Measurements of the attenuation can give an indication of the loss mechanism operating in the crystal and abstracting energy from the ultrasonic wave.

1070 FATIGUE AND ULTRASONIC ATTENUATION
R. Truell and A. Hikata
Symposium on Nondestructive Testing
ASTM Technical Pub. 213, 1957

Experiments conducted in this laboratory over the past several years have shown that appreciable changes occur in the propagation and recovery behavior of ultrasonic waves in materials during stress or fatigue cycling. Although most of the exploratory work has been done on three types of aluminum, the method is not restricted to aluminum. The following is a brief survey of the effects observed, and no explanation of the observed behavior is offered. Some explanation is offered in an earlier report by the authors. The results of the work show that in all cases studied the ultrasonic attenuation increases as a function of the number of cycles of loading and unloading. The loading in these experiments was done in tension and in tension and compression. The form of the attenuation-cycles curve depends among other things on the magnitude of the load and the speed of cycling.

1071 THE EFFECT OF HYDROGEN ON ULTRASONIC ATTENUATION AND VELOCITY MEASUREMENTS IN TITANIUM
C. F. Ying and R. Truell
Brown University, Providence, R. I., OOR Contract No. D. A.-19-020-ORD-1512
Acta Metallurgica, May 1954

This report covers the investigation of titanium before and after heat treatment in hydrogen by ultrasonic attenuation and velocity measurements in the range of 10 to 50 Mc/s. Attenuation decreased greatly with increased hydrogen content.

1209 METHODS FOR NONDESTRUCTIVE EVALUATION OF PHYSICAL PROPERTIES IN RUBBER SOLID COMPOUNDS
J. G. Martin
IRE-Western Electronic Show and Convention
Paper No. 37/1, 1961

This paper points out that correlation and measurements effecting changes of mechanical behavior are possible, when interference effects of the transducer-specimen method are predictable. Therefore, the use of ultrasonic attenuation to detect the characteristics of heavily loaded elastmeric materials is feasible.

1295 METHOD FOR MEASURING ATTENUATION OF ULTRASONIC LONGITUDINAL WAVES IN PLASTICS AND ROCKS
M. Auberger and J. S. Rinehart
Journal of the Acoustical Society of America, December 1960

This report covers the use of the pulse technique for measurement of attenuation of longitudinal waves in rocks and plastics. Frequency range data is given from 250 Kc to 1000 Kc for granite and Plexiglass.

1349 IMPLICATIONS OF ULTRASONIC ATTENUATION TO NONDESTRUCTIVE TESTING
J. K. White, R. W. McClung and J. W. Allen
Oak Ridge National Laboratory
ORNL-2651 April 1959

In order to relate ultrasonic inspection data to actual conditions inside a metal part, it is essential that the inspector have some knowledge of attenuation as it affects ultrasound. This paper briefly reviews the theory of attenuation of ultrasonic energy. It discusses the first part of a study being conducted for the purpose of understanding and evaluating the large losses encountered in cast and welded steels. The equipment required and techniques employed for measuring attenuation are described. The results of these attenuation measurements are described with special reference to weld inspection.

1393 THEORY OF ULTRASONIC ATTENUATION IN CYLINDRICAL AND RECTANGULAR WAVEGUIDES
E. F. Carome and J. M. Whiting
Journal of the Acoustical Society of America, February 1961, p. 187-197

Theoretical attenuation studies in cylindrical and rectangular waveguides is discussed. Both the receiver and the source were of the same size. Path length acoustic loss is computed for the various waveguide and source configurations.

1398 RAYLEIGH AND STOCHASTIC SCATTERING OF ULTRASONIC WAVES IN STEEL
E. P. Papadakis
Watertown Arsenal Laboratories, Watertown, Mass.
Journal of Applied Physics, Vol. 34 No. 2, February 1963, p. 265-269

Ultrasonic attenuation measurements in SAE 4150 steel at various stages of heat treat were made utilizing 5 to 100 Mc frequencies. Changes in grain diameter and anisotropy changes the attenuation which is in fairly good agreement with theories of scattering by grains in metals. Tempering reduces the attenuation by a factor of 3 without a change in grain size.

1456 ULTRASONIC ATTENUATION IN LEAD
A. R. MacKintosh
Cavendish Lab., University of Cambridge
Proceedings of the Royal Society, Vol. 271, No. 1344, 1 January 1963, p. 88-104

Absorption studies of longitudinal waves in pure single crystals have been made at 1.2°K in a transverse magnetic field. Results are generally consistent, as suggested by Gold, with the Fermi surface of lead. Detailed studies of the magneto-acoustic oscillations were also conducted. Absolute magnitude of attenuation in a magnetic field was also studied and results given.

1485 VISUALIZATION OF ULTRASONIC EXTINCTION NETWORK IN COARSE GRAINED URANIUM
R. S. Sharpe and S. Aveyard
Applied Materials Research, October 1962, p. 170-176

This paper describes the use of the ultrasonic pulse technique as applied to detection of grain refining treatment in cast uranium bars. Core and rim regions were inspected at the same time. Coarse grained uranium produced high attenuation at 6 Mc pulses.

1492 ULTRASONIC ATTENUATION UNIT AND ITS USE IN MEASURING ATTENUATION IN ALKALI HALIDES
B. Chick
Journal of the Acoustical Society of America, Vol. 32, No. 2, February 1960, p. 186-193

This paper describes an ultrasonic attenuation unit developed for measuring attenuation and velocity in the range of 5-200 mc/sec frequencies. Also reported are attenuation measurements of single crystals of NaCl.

1552 A RECORDING ULTRASONIC INTERFEROMETER AND ITS ALIGNMENT
J. L. Stewart and E. S. Stewart
Journal of the Acoustical Society of America, January 1952, p. 22-26

This article consists of three parts, a) describing a circuit using r. f. amplification for converting the ultrasonic interferometer to a selfrecording instrument for rapid determination of coefficients of gases at low pressures. b) describes sources of errors, their detection, and correction. c) Contains data velocities, attenuation, and reflection in Helium.

1627 ULTRASONIC ATTENUATION AND VELOCITY IN THREE TRANSFORMATION PRODUCTS IN STEEL
E. P. Papadakis
Bell Telephone Laboratories, Allentown, Pennsylvania
Journal of Applied Physics, Vol. 35, No. 5, May 1964

Ultrasonic attenuation measurements were applied to three products of steel, namely pearlite with ferrite, barnite and martensite, utilizing 2-100 mc/sec with longitudinal and transverse waves. Attenuation was highest in pearlite, intermediate in barnite and lower in martensite. Attenuation and velocity tables are included.

1628 ULTRASONIC ATTENUATION IN SINGLE-CRYSTAL CADMIUM
G. Abowitz
Cornell University, Ithaca, New York
Journal of Applied Physics, Vol. 34, No. 5, May 1963

Attenuation of longitudinal and shear waves in the range of 5 to 60 megacycles per sec. frequency range was measured in cadmium single crystals at 300°K. Present results indicate lack of understanding of acoustic damping in cadmium and zinc.

1631 EVALUATION OF A RESIN-CERAMIC HEAT-SHIELD MATERIAL BY ULTRASONIC TECHNIQUES
G. E. Lockyer
Avco Corp., Lowell, Mass., Materials Evaluation, March 1965

This paper discusses procedures for performing nondestructive evaluations on a resin-ceramic material used as a heat shield for missile re-entry applications. The evaluation made use of ultrasonic techniques, and, in particular, velocity and attenuation measurements. Procedures for measuring these ultrasonic properties are described, and studies involving their correlation with material properties such as bulk density, ultimate tensile strength, and modulus are discussed. The correlation presented indicates the feasibility of implementing such ultrasonic measurements as an aid in material development programs, as well as a quality control tool for monitoring the production phase.

1636 ABSORPTION OF ULTRASONIC WAVES IN SOLIDS
M. Redwood AD 281495
Frankford Arsenal
Translated from Revue de Metallurgie, Vol. 56, 1959, p. 172-180

The first part of this report discusses several factors which introduce errors into the determination of the ultrasonic attenuation of low loss materials. A method for evaluating the losses due to reflection at the transducer specimen interface is presented and the interference effects caused by the simultaneous generation of signals which have various modes of propagation or vibration are discussed in detail. The second part of the report presents a rapid over-all view of the various theories used to explain the frequency and temperature dependence of friction damping in metals. An extensive bibliography is presented.

1653 FREQUENCY BANDWIDTH CONSIDERATIONS IN ULTRASONIC TESTING
C. P. Merhib
U. S. Army Materials Research Agency, Watertown, Mass
WAL TR 143.7/1, January 1963

The determination of flaw geometry and flaw orientation is a complex and difficult problem whose solution has been sought since the beginning of ultrasonic testing. In recent work at Watertown Arsenal Laboratories significant advances have been made toward solution of this problem, but many details have yet to be resolved. The frequency bandwidth effects in relation to the above problem and the influence of bandwidth on amplitude indications from test blocks commonly used to calibrate equipment sensitivity are discussed. In addition, an outgrowth of the above work is a realization of the necessity for periodic evaluation of transducers.

1661 ULTRASONIC SCATTERING AND ATTENUATION IN POLYCRYSTALLINE COPPER AND BRASS
D. W. Krautkopf
Journal of the Acoustical Society of America, July 1960, p. 824-835

The subject title has been studied with the primary objective being that of direct observation of the scattered radiation, and a study of attenuation where pulse patterns were caused by excessive scattering or mode conversion. Attenuation varied as expected for elastic hysteresis damping.

1667 MEASUREMENT OF ULTRASONIC ATTENUATION AS METHOD FOR QUALITY CONTROL OF WROUGHT AND CAST STEEL PARTS
E. Krainer
Materials Testing-Materiaux Vol. 4, No. 12, December 20 1962, p. 463-469

Summary of theory of interpreting attenuation as indication of structural or physical and mechanical properties; examples of application. 35 refs.

1709 ULTRASONIC POLE PATTERNS IN SAE 4150 STEEL
P. F. Sullivan
U. S. Army Materials Research Agency, Watertown, Mass.
WAL TN 143/42, January 1963, 22 p. w/illus.

The phenomenon of ultrasonic pole patterns arising from double refraction is explained and preliminary experimental results, graded as to reliability, are presented. Special emphasis is placed on instrumentation and technique with a thorough analysis of errors and detailed suggestions for improvement. The extensive field of application of this phenomenon as a tool for testing materials is indicated.

1726 SPECIAL TECHNIQUES OF NONDESTRUCTIVE TESTING OF METALLIC WORKPIECES
H. J. Rodewald and C. Studer
Metall, Vol. 17, No. 1, January 1963, p. 24-26

Extension of previous work (see Engineering Index 1961, p. 992); immersion apparatus for testing plate by ultrasonic attenuation; ultrasonic testing of continuously cast aluminum billets in water tank of continuous casting machine; advantages of foil and dispersion lacquer techniques in penetration testing of defects in metal surfaces; stereoscopic x-ray testing of welds.

1968 ON THE ATTENUATION OF ULTRASONIC WAVES IN CHROME-NICKEL AUSTENITIC STEELS
P. Midecke
HB 5115, Materialprufung, Vol. 3, No. 1, 1961, p. 1-4

Application of nondestructive procedures for testing Cr-Ni austenitic steels is severely limited, since magnetized particle testing fails completely and ultrasonic testing is difficult and sometimes impossible for parts some 10 mm (0.4 in.) thick. Compared with unalloyed structural steels, the propagation of ultrasonic waves is considerably interfered with. With increasing carbon content, Cr-Ni austenitic steels contain increasing amounts of precipitates. Because of the resulting increased acoustical attenuation, an investigation into the limits of applicability of ultrasonic testing seemed desirable.

1974 INVESTIGATION ON THE MEASUREMENT OF SOUND ATTENUATION AND ULTRASONIC DETERMINATION OF DEFECT SIZE (IN STEEL FORGINGS)
W. Knorr and H. G. Ricken
HB 5656, Archiv Eisenhuttenwesen, Vol. 33, No. 5, 1962, p. 317-325

The significance of the measurement of sound attenuation and the determination of defect size lies in the important fact that the ultrasonic technique has actually been converted into a quantitative technique and ultrasonic test results can now be interpreted objectively.

1975 DETERMINATION OF DEFECT SIZE IN FORGINGS BY AN ULTRASONIC TECHNIQUE
P. Opel and G. Ivens
HB 5655, Archiv Eisenhuttenwesen, Vol. 33, No. 5, 1962, p. 311-316

Modification of Krautkramer's technique for the determination of ultrasonic beam attenuation and defect size in forgings by the use of the back echo instead of the reference echo.

2058 ULTRASONIC METHODS IN THE STUDY OF FATIGUE AND DEFORMATION IN SINGLE CRYSTALS OF ALUMINUM AND SODIUM CHLORIDE
B. Chick, et al N63-15806
Brown University, Providence, R. I.
ASD-TDR-62-186, February 1963

The use of ultrasonic methods for studying defect formation and its consequences in connection with stress cycling and deformation in aluminum and sodium chloride single crystals is the subject of this report. The observed ultrasonic changes appeared closely associated with changes in dislocation behavior. To establish this deformation, experiments were used in such a way that results could be related to the behavior of the slip systems and to their orientation. Important equipment improvements have been made for automatic recording of attenuation and velocity measurements.

2066 THEORETICAL AND EXPERIMENTAL STUDIES OF PRESSURE PROFILES IN ULTRASONIC WAVEGUIDES
E. F. Carome and J. B. Lastovka
Journal of the Acoustical Society of America, Vol. 35, No. 5, May 1963, p. 645-650

Investigations have been conducted in an attempt to confirm results of attenuation vs pathlength in liquid-filled waveguides. Theoretical profiles, pressure-free walls and rigid walls were computed. Experimental results confirm the theoretical predictions for guides with pressure-free walls.

2101 ULTRASONIC MEASUREMENT TECHNIQUES APPLICABLE TO SMALL SOLID SPECIMENS
H. J. McSkimin
Journal of the Acoustical Society of America, July, 1950, p. 413-418

Velocity of propagation measurements and elastic constants may be conducted by phase comparison at high ultrasonic frequencies for single crystals or other small solid specimens. The pulse technique utilizing both longitudinal and transverse waves permits determination of the wavelengths in the acoustic path, along with measurement of phase shift at reflecting interfaces. Theoretical analysis is included along with illustrative data.

2107 ULTRASONIC METHODS IN THE STUDY OF FATIGUE AND DEFORMATION IN SINGLE CRYSTALS
B. Chick et al N63-18393
Brown University, Providence, R. I.
ASD-TDR-62-186, Pt. II, April 1963, 76 p.

Ultrasonic methods for studying defect formation and motion in connection with deformation and stress cycling experiments in aluminum and sodium chloride single crystals is the subject of this report. Large single crystals of sodium chloride, deformed in tension, were measured similarly to aluminum for the purpose of comparing the dislocation damping and recovery effects in an ionic crystal with those in a metal. Also there was significant information from electrical conductivity measurements made concurrently with attenuation and velocity measurements. Al single crystals were also stress cycled in tension and compression at levels much higher relative to yield stress and breaking stress than polycrystalline samples.

2122 METHOD OF MEASURING AND ANALYSING WAVE MOTION
W. K. R. Lippert
Acustica, Vol. 12, No. 3, 1962, p. 125-139, SNT Journal, May-June 1963

Acoustic propagation parameters, i.e. attenuation constant and characteristic impedance, of a sample can be determined from measurable quantities of acoustic waves in the input ducts that terminate the sample of material. A model sample was used that consisted of numerous cylindrical tubes in parallel. Measurements of the reflection and transmission factors (complex) permit the propagation parameters to be determined. Corrections for transition zone losses between the duct and the sample can be made by substituting a plate for the sample, the plate to have the same hole configuration as the sample cross section. Additional measurements with the plate in place provide information so that corrections in magnitude and phase can be applied to the propagation parameters.

2217 A METHOD FOR DETERMINING THE PROPAGATION CONSTANTS OF PLASTICS AT ULTRASONIC FREQUENCIES
H. J. McSkimin
Journal of Acoustical Society of America, Vol. 23, July 1951, p. 429-434

Description of a technique suited for measuring attenuation and phase-shift constants in plastics. 5-50 Mc frequencies were utilized with either transverse or longitudinal waves. Data is given for polyethylene and nylon.

2246 INFLUENCE OF MICROSTRUCTURE IN ULTRASONIC EXAMINATION OF STAINLESS STEEL WELDS
E. Holmes and D. Beasley
Iron and Steel Institute Journal, Vol. 200, Pt. 4, April 1962, p. 283-290

Austenitic stainless steel welds have high ultrasonic attenuation and abnormal beam transmission, thereby complicating flaw detection. The cause and occurence are discussed. Carbides and ferrite did not appear to increase scattering when finely divided in large inclusions.

2385 ATTENUATION OF PURE ELASTIC MODES IN NaCl SINGLE CRYSTALS
E. P. Papadakis
Journal of Applied Physics, Vol. 34, No. 7, July 1963, p. 1872-1876

A discussion of dislocations as being the major source of attenuation in single crystals; pulse echo attenuation for longitudinal and transverse measurements along 3 pure mode axes in subject specimens.

2554 ULTRASONIC CONTROL OF FATIGUE DAMAGE TO MATERIALS
P. V. Ponomarev
Industrial Laboratory, Vol. 28, No. 11, November 1962
Translation (Russian). Published July 1963, p. 1429-1431

The relationship between the accumulation of fatigue damages in a material absorption of ultrasonic sound during the process of fatigue inspection is considered. It is established that the moment of failure onset of a part can be determined from the character of change of the ultrasonic attenuation curve. The possibility of creating an instrument for the continuous or periodic inspection for fatigue damages of materials is pointed out.

2671 AN IMPROVED BONDING CLAMP AND AUXILIARY EQUIPMENT FOR ULTRASONIC MEASUREMENTS
P. F. Sullivan
U. S. Army Materials Research Agency, Watertown, Mass.
AMRA TR 64-06, April, 1964

A new bonding clamp for the production and examination of coupling between an ultrasonic transducer and a specimen is discussed both from the operational and constructional points of view. In addition to the clamp itself, auxiliary equipment now in the development stage is also discussed. Most significant of this equipment is an automatic attenuation monitor which gives a continuous readout of the ultrasonic attenuation of the specimen. With this apparatus, it is possible to determine the attenuation as a function of rapidly varying dynamic conditions.

2910 THE EFFECT OF THE FREQUENCY OF SOUND ON ITS ABSORPTION BY A METAL IN A MAGNETIC FIELD
M. S. Svirskii
Soviet Physics, JETP, Vol. 17, No. 2, August 1963, p. 426-428

Consideration is given to gigantic quantum oscillators when absorption of sound by a metal occurs in a magnetic field due to the variations of frequency. Further experimental possibilities of such effects are also considered.

2953 INSPECTION OF BURNT STEEL IN CALIBER .30 CARBINE BARRELS
R. D. Korytoski
Springfield Armory, Springfield, Mass.
Tech. Rpt. SA-TR1-1012, 22 April 1957, 12 p.

A serious condition of burnt steel in supplied barrel forgings necessitated the development of nondestructive test procedures to detect this condition and to salvage rough forgings, semifinished and finished barrels manufactured from lots containing this condition. A number of methods were investigated including visual examination, magnetic particle, magnetic analysis, dye penetrant and ultrasonic attenuation. Rapid and reliable inspection procedures were developed with the use of ultrasonic attenuation techniques. Approximately 185,000 barrels in various manufacturing stages were inspected by use of this method. CONCLUSIONS: Proper interpretation of ultrasonic attenuation patterns provides a method to detect burnt steel. The method is sensitive, reliable, and rapid. Dye penetrant methods provided means of detecting burnt steel in semifinished barrels; however, the methods were not economical because of the time required for application. Visual method of inspection after etching or pickling process was useful in the establishment of standards for the ultrasonic attenuation method, but by itself was neither reliable nor practical for 100% inspection. Methods utilizing comparison of magnetic properties could not be applied in inspection of burnt steel since correlation did not exist between magnetic test results and microscopic examinations.

3039 AN INVESTIGATION OF ULTRASONIC INSPECTION METHODS FOR SINTERED POWDERED METAL COMPACTS
R. D. Korytoski and E. H. Abbe AD-252184
Springfield Armory, Springfield, Mass.
3 October, 1960, 34 p.

Progress is reported on a continuing study to determine the feasibility of utilizing ultrasonic attenuation methods in nondestructive inspection of cast and sintered small arms components. Studies are summarized concerning techniques and equipment designed and developed for ultrasonic measurement of cast, sintered, and wrought ferrous material. Influence of variables such as density, grain size, surface preparation, filler substances, degree of sintering, and specimen geometry on ultrasonic attenuation is discussed.

3062 ULTRASONIC INSPECTION USED TO DETECT HYDROGEN ATTACK
J. Bland
Petroleun Refiner, July 1958, also Sperry Reprint 50-875

An ultrasonic method is presented which is capable of detecting damage produced in steel by high temperature hydrogen attack. Previously this method had been used successfully to detect burning in aluminum. Normal multiple back reflections can be obtained on sound material, whereas damaged areas so attenuate the signal that no back reflection or a reduction in the back reflections is received.

3071 ULTRASONIC TECHNIQUES FOR INSPECTING PLASTICS
J. B. Ramsey
Automation Industries, Inc.
Western Plastics Magazine, Technical Report No. 100, September 1963, p. 33-35

This is a good introductory article on the subject of ultrasonic testing of plastics. It covers acoustic impedance and attenuation, modulus of elasticity, density, and Poisson's Ratio. Several examples of plastics tested are given and the three common methods for ultrasonic testing are explained. They are: direct reflection, reflector technique, and through transmission. Several figures are included, including a C-scan presentation of an unbonded plastic-steel point.

3086 ULTRASONIC ATTENUATION STUDIES OF DIE BLOCK STEELS
R. D. Korytoski and R. H. Brockelman
Springfield Armory, Springfield, Mass.
Report SA-TR-19-1513, December 1964

This investigation was undertaken to determine the feasibility of using ultrasonic attenuation measurements to nondestructively evaluate die block steels for other than gross defects. Both pulse echo and comparator type measurement were made on samples of die block steels in various conditions of heat treatment. Observed attenuation values correlated with the prior austenitic grain size of hardened and tempered specimens. Variations of attenuation within die blocks were used as an indirect measure of structural uniformity. The method appears to be feasible for the evaluation of certain conditions in die blocks.

3112 THE USE OF ULTRASONIC METHODS TO DETERMINE FATIGUE EFFECTS IN METALS
R. Truell, B. Chick et al
Metals Res. Lab., Brown University, Providence, R. I., Contract AF-33(616)5884, Rpt. for 16 June 58-15, June 1959, 23 p.

An investigation was made to detect and follow physical changes in materials, primarily Al, during stress cycling by means of high frequency ultrasonic attenuation and velocity measurements. A discussion is presented of observed changes in ultrasonic attenuation and velocity in commercially pure 1100 Al (Alcoa) when subjected to slow continued stress cycling (1 to 6000 c) and a delayed recovery phenomenon that appeared when the cycling was interrupted. The development of an automatic instrument to measure and record ultrasonic attenuation changes is also discussed.

3126 ULTRASONIC ATTENUATION AND VELOCITY MEASUREMENTS IN QUARTZ
T. Fitzgerald and R. Truell AD-257 086
Metals Res. Lab., Brown University, Providence, R. I., 4 May 1961, 30 p.

The frequency dependence of the attenuation of compressional waves in X-cut quartz obeys an approximate square law consistent with the dislocation damping theory which predicts a square-law frequency dependence up to a resonant frequency. The behavior of the attenuation as a function of temperature below 100 K is in agreement with that predicted by a phononphonon process. Above 40 K the thermal conductivity varies approximately as 1/T while the specific heat increases linearly with the temperature between 40 and 150 K. The temperature dependence of the velocity measured in this experiment indicates that it remains constant at a value of 5.75 K X 10 to the 6th power cm/sec to within + or - 0.02%. In the region where the attenuation is rapidly changing there is apparently no associated velocity change.

3168 ULTRASONIC ATTENUATION IN SUPERCONDUCTORS
T. Tsuneto AD 257 610
Illinois University, 31 August 1960, 14 p.,
TR-22

A general treatment of ultrasonic attenuation of both longitudinal and transverse waves in super conductors, valid for an arbitrary mean free path, is given on the basis of the Bardeen-Cooper-Schrieffer theory. The interaction between the ultrasonic waves and electrons is assumed to be given by a self-consistent electromagnetic field. Instead of the customary theory of the attenuation based on the Boltzmann equation, a different formulation is developed using the density-matrix formalism. The ratio of the attenuations in superconducting and normal metals for the longitudinal wave turns out to be approximately independent of the mean free path. The attenuation of the shear wave due to electromagnetic interaction shown to be very small in the superconducting state.

3198 ATTENUATION OF SOUND IN A GERMANIUM CRYSTAL AT ULTRA-HIGH FREQUENCIES AND LOW TEMPERATURES
E. R. Dobbs, B. B. Chick and R. Truell AD 254 572
Metals Res. Lab., Brown University, Providence, R. I., 29 June 1959, 3 p. (Reprint from Physical Review Ltrs 3:332-334, 1 October, 1959)

The ultrasonic attenuation of compressional and shear waves in a high-purity crystal of germanium were measured at frequencies up to 650 mc and at temperatures down to 1.5 K. At room temperature there is some evidence for the dislocation loss mechanism, but at low temperatures the attenuation is very small. The specimen was of n-type germanium, with room temperature resistivity 45 ohm-cm and net donor concentration 1 x 10 to the 12 power/cc.

3261 THE PROPAGATION OF ULTRASONICS IN SUSPENSIONS OF LIQUID GLOBULES IN ANOTHER LIQUID
P. A. Allison, E. G. Richardson
Proceedings of the Physical Society, Vol. 72, Part 5, No. 467, p. 883, November 1958

Studies conducted on ultrasonic attenuation of two liquids mixed together, one containing globules in suspension. Effects of viscocity of the liquid and globules on attenuation is studied. Relevant factors include scattering and pulsation of the globules.

3262 THE PROPAGATION OF ULTRASONICS IN SUSPENSION OF PARTICLES IN A LIQUID
J. Busby, E. G. Richardson
Proceedings of the Physical Society, Vol. 69, 1956, p. 193

The measurement of sound propagation of solid particles in suspension in water using frequencies of 1 to 10 Mc/s is described. Results are in good agreement with theory. Absorption is linear up to a concentration of 18% by volume with glass or silica particles in suspension.

3286 ULTRASONIC PROPAGATION IN LIQUID AMMONIA AND AMMONIA SOLUTIONS OF SODIUM BROMIDE, SODIUM IODIDE, LITHIUM AND SODIUM METAL
E. J. Zdanuk AD-101 737
Boston University, Boston, Mass., 19 March 53-31, March 1956, 51 p.

The velocity and attenuation of sound in liquid ammonia and solutions of electrolytes and metals have been measured by the pulse technique from 4 to 52 megacycles over the temperature range -35° to -70°C. The high velocity of sound in ammonia does not support the predictions of free volume theory. The attenuation in ammonia exceeds the calculated classical attenuation. The ratio obs./calc. for ammonia is consistent with the properties of an associated liquid. The velocity of sound in ammonous NaBr and NaI solutions relative to pure solvent and the corresponding adiabatic compressibilities resemble the nature of these properties in aqueous systems and are qualitatively explainable in terms of the electrostrictive concept of ionic solutions. The attenuation of sound in the salt solutions was substantially larger than in corresponding aqueous solutions. In ammonia solutions of Na and Li, the decreases of velocity with increasing concentration are 3 to 5 times the decreases observed for NaI at equivalent concentrations. The compressibilities of the metal solutions increase with concentration in contrast with the decreases observed for aqueous or ammonous electrolytic solutions. This behavior is tentatively explained in terms of an expanded metal structure consisting of ammoniated positive ions and ammoniated electrons in a quasi lattice in which the electrons still serve as bonding electrons giving the system its cohesive energy. The attenuation of sound in the metal solutions exceeds the classical prediction. In addition a maximum in the attenuation dependence on concentration was indicated which may be indicative of electron pairing equalibria in the metal solutions.

3300 THE FREQUENCY DEPENDENCE OF ULTRASONIC ATTENUATION IN GERMANIUM
A. Granato and R. Truell AD 91634
Metals Research Lab., Brown University, Providence, R. I.
Tech Rpt, March 1956, 32 p.

The frequency dependence of the ultrasonic attenuation of compressional waves propagating in the (100) direction in Ge were measured, and 2 components were separated. The first is a result of diffraction and is the principal loss at 1f's. The second is a loss which increases almost with the square of the frequency up to 300 mc and can be accounted for with reasonable values of the dislocation density and loop length. A damping constant (B) range of 8 x 10-5 = B = 14 x 10-5 was computed for a loop length (L) range of 8 x 10-5 = L = 10-4 cm. A percentage modulus change (E/E) of 0.013% was calculated for a dislocation density ( ) of 19-6 cm -2 and an L of 9 x 10 cm. The LF expression for the attenuation B = 3 x 10-17-2 db/usec was obtained for = 3.7 x 10-6 cm -2, L = 9 x 10-5 cm, and B = 1.1 x 10-4 where f is the frequency. Measurement of the attenuation of shear waves propagated in the 100 direction indicated a double refraction effect. Specimens with high compressional wave attenuations also appeared to have high shear-wave attenuations.

3303 TRANSMISSION OF ULTRASONIC VIBRATION IN METALS
R. W. Mebs AD 92 032
National Bureau of Standards
Quart Rpt. No. 3, 1 January 1931, March 1956, 25 April, p. 24

Measurement of ultrasonic transmission was continued on 1/2-, 1-, 20-, and 3-in. test specimens of SAE a4340 steel at 10 mc for 1-, 30-, and 7-usec nominal pulse lengths. The crystals originally attached to the buffer lines appeared to be in satisfactory condition. Tests were completed on SAE 4340 steel in the air-cooled condition, as furnace cooled from 1550°F, and after double tempering subsequent to oil quenching from the austenitizing temperatures of 1550°F and 1650°F, respectively. Tests were also completed on isoleastic alloy F in the as received condition. Only net values of attenuation and delay time are recorded. A survey of values of pulse length and rise time indicated no significant variation of output pulse shape as obtained with the buffer lines in comparison with those obtained with a successively increasing length of test specimens. The principal distortion of the sent pulse appeared to occur in the transducer. Curves are presented of the variation of net attenuation with specimen length for the 2 as received materials, which indicate an increase in attenuation with length. Attenuation length curves were obtained for air-cooled SAE 4340 steel demagnetized at 60 cycles and remagnetized with a force of about 500 oer; remagnetization lowered the attenuations of all but the 3 in. specimen below the values obtained before demagnetization. Slopes of the net delay time length curves for SAE 4340 steel as received and after various heat treatments were almost identical. (See also AD 83 783).

3306 ACOUSTICAL RESEARCH
R. B. Lindsay AD-104 544(a) - AD-104 544(h)
Brown University, Providence, R. I.
Technical Report No. 8, July 1956

Underwater sound reflection from a corrugated surface. Relative absorption of 10mc/sec longitudinal sound waves in a superconducting polycrystalline tin rod. Pressure coefficient of the dielectric constant of water. Ultrasonic attenuation in superconducting indium. On the application of the kinetic theory of liquids of Born and Green to the problem of the calculation of the volume viscosity. Propagation of sound pulses in a dispersive medium. Tank wall lining for underwater sound use. Vibrational relaxation in N_2O - H_2O and N_2O - D_2O mixtures.

3325 ORIENTATION DEPENDENCE OF ULTRASONIC ATTENUATION IN ZINC
P. C. Waterman AD-206 161
Metals Res. Lab., Brown University, Providence, R. I., 24 January 1958, 6 p.

The attenuation of plane elastic waves in the megacycle region is investigated for several different propagation directions in single crystalline zinc. Results are in qualitative agreement with the losses predicted theoretically due to dislocation damping and thermoelastic effects, and in addition losses not accounted for by the available theory are observed.

3407 AN EXPERIMENTAL SYSTEM FOR ULTRASONIC ATTENUATION, MEASUREMENTS IN SOLIDS IN THE UPPER KILOCYCLE RANGE
R. E. Booker, F. H. Sagar
University of Auckland
Ultrasonics, Vol. 1, October - December 1963

The measurement of acoustic attenuation in small samples of low loss solids in the range 50 kc/s to 10 mc/s has, up to now, proven difficult. When the pulse method is applied below 10 mc/s it is not easy to perform satisfactory corrections for diffraction and mode-conversion errors. The resonance method, in the form most frequently used, is suitable for elastic constant and attenuation measurements over the lower part of the kilocycle range, i.e., 1-20 kc/s. This paper is an account of various modifications in the experimental set-up of the resonance method of attenuation measurements, whereby good signal/noise ratios have been realized up to 700 kc/s attenuation measured from 20 kc/s to 600 kc/s, and output signals generated from 0-5v down to 10 micro v.

3451 INVESTIGATION OF ULTRASONIC SURFACE WAVE PROPAGATION ALONG THE BOUNDARY BETWEEN LIQUID AND SOLID
I. A. Victorov
Akust. Zh. 9, No. 2, 1963, Ultrasonics, October-December 1963

Automatic NDT by ultrasonic immersion techniques offers many advantages, and in this article the effect of the immersion liquid on the characteristics of surface waves are investigated both theoretically and experimentally. Velocity and attenuation in steel and aluminium immersed in water, transformer oil and glycerine were studied at a number of frequencies, and there was agreement of about 10-15% between theoretical and experimental results. (1 table, 6 figures, 3 references). In a consecutive paper (p. 171) Victorov and Zubova present an experimental and theoretical study "On directivity patterns of Lamb's and Rayleigh's wave radiators."

3457 FREQUENCY DEPENDENCE OF ULTRASONIC ATTENUATION AND VELOCITY ON PLASTIC DEFORMATION
A. Hikata, R. Truell
Brown University, Providence, R. I.

The dependence of ultrasonic attenuation and velocity on plastic deformation in 2S aluminum is compared at two frequencies, five and ten megacycles, and the comparison shows agreement as regards to frequency dependence with what one can expect from dislocation damping theory.

3471 FEASIBILITY STUDY TO DETERMINE WHETHER ULTRASONIC TECHNIQUES CAN BE USED TO MEASURE MECHANICAL PROPERTIES OF CAST POLYURETHANES INTENDED FOR APPLICATION AS SOLID PROPELLANT BINDERS
Aeronautical Systems Division, Physics Lab, Wright-Patterson AFB
Report No. ASD-TDR-62-886, Final Report, July 1963, 32 p. w/illus.

The purpose of this project is to determine the feasibility of utilizing ultrasonic techniques to measure mechanical properties of cast polyurethanes. Two suppliers prepared and delivered several series of specimens simulating both binder and propellant materials in various conditions of aging. Sperry Products performed ultrasonic examination of these specimen materials with the objective of finding ultrasonic properties which would indicate their physical condition. Results of tests indicate a significant dependence of both shear wave attenuation and relative acoustic impedance of certain specimen materials on their condition of aging.

3493 DETERMINATION OF COMPLEX MODULI OF VISCOELASTIC MATERIALS WITH ULTRASONIC PULSE METHOD
H. A. Waterman
Kolloid-Zeit, Vol. 192, No. 1-2, October 1963/II, p. 1-16

Real and imaginary parts of 2 independent elastic moduli can be found from velocity and attenuation of ultrasonic waves as measured with aid of modified rotating plate method introduced by Y. Maeda; measurements on isotactic polypropylene and high density polyethylene; measurements of velocity and attenuation of longitudinal and transverse waves in polyethylenes. 26 refs.

3587 PRECISION ULTRASONIC MEASUREMENTS FOR MICROBUBBLE RESEARCH
W. R. Turner AD 413052
Vitro Laboratories, Silver Spring, Md., July 1963

New techniques are described for measuring ultrasonic attenuation and velocity in water at 3 frequencies in the 1-10 mc range. Basic instrument configuration is that of a Mach-Zehnder type interferometer, w/ one path including an ultrasonic cell, the other a precision attenuator. The cell consists of a 3 frequency transducer, a supporting cage, and a reflector. In operation a signal is switched for a short time to the cell then returned to the attenuator path. The pulse is delayed by transit through the cell, is mixed w/ the attenuator signal to obtain a null and displayed on a CRT. Attenuation is determined from the attenuator setting, and velocity from the frequency interval between nulls.

3588 COMPARISON OF ULTRASONIC EFFECTS IN PIEZOELECTRIC AND SIMPLE DEFORMATION POTENTIAL SEMI-CONDUCTORS
J. Mertsching
Physica Status Solidi, Vol. 4, No. 2, 1964, p. 453-458

Ultrasonic attenuation or amplification and acousto-electric field in nonpiezoelectric semiconductor with large deformation potential are obtained from data on piezoelectric semiconductor, piezoelectric field being replaced by deformation potential field and by adding new term to sound velocity.

3596 SIMULTANEOUS MEASUREMENT OF ULTRASONIC ATTENUATION AND YIELD STRENGTH OF Mg SINGLE CRYSTALS
W. F. Chiao, R. B. Gordon
Applied Physics Letters, Vol. 3, No. 5, September 1 1963, p. 88-89

Sharp yield occurs when stress in some part of test specimen becomes great enough to unpin dislocations, after which plastic flow propagates rapidly through sample; one of major contributions to total ultrasonic attenuation, α in metal single crystal is from dislocation damping; 2 phenomena can be related; strain-stress curves for single Mg crystal are related to ultrasonic attenuation observed during deformation.

3604 DIFFRACTION OF ULTRASOUND RADIATION INTO AN ELASTICALLY ANISOTROPIC MEDIUM
E. Papadakis
Bell Telephone Laboratories, Inc., Allentown, Penn. October 1963
Reprint, Journal of the Acoustical Society of America, Vol. 36, No. 3, March 1964

This article discusses the scaled diffraction loss-distance characteristics as a use for computing diffraction corrections for ultrasonic attenuation. Ultrasonic pulse echo, diffraction loss-distance characteristics for various crystal anisotropics are computed.

3637 ULTRASONIC ATTENUATION AND THE PHYSICS OF SOLIDS
R. Truell
Brown University, Providence, R. I.
Symposium on Physics and Nondestructive Testing, Argonne National Laboratory, 1960, p. 109-126

An outline is given of those interactions between ultrasonic stress waves in solids and the various types of absorbing or scattering elements which can be studied by observing the propagation behavior of the stress waves. A discussion will be given of what can be learned about solids and defects in solids from the physical point of view. Specific examples related to changes in mechanical properties and changes induced by radiation effects are given.

3693 FEASIBILITY STUDY TO DETERMINE WHETHER ULTRASONIC TECHNIQUES CAN BE USED TO MEASURE MECHANICAL PROPERTIES OF CAST POLYURETHANES INTENDED FOR APPLICATION AS SOLID PROPELLANT BINDERS

A. M. Murdock, H. E. Van Valkenburg AD 415828

Aeronautical Systems Div. Dir/Materials and Processes, Physics Lab. Wright-Patterson AFB, Ohio
RPT. No. ASD-TDR-62-886, Final Rpt, July 1963, 32 p.

The purpose of this project is to determine the feasibility of utilizing ultrasonic techniques to measure mechanical properties of cast polyurethanes. For this project 2 suppliers prepared and delivered to Sperry Products several series of specimens simulating both binder and propellant materials in various conditions of aging. Sperry Products performed ultrasonic examination of these specimen materials with the objective of finding ultrasonic properties which would indicate the materials' physical conditions. Results of test indicate a significant dependence of both shear wave attenuation and relative acoustic impedance of certain specimen materials on their condition of aging.

3695 ATTENUATION OF ULTRASONIC STRESS WAVES IN CADMIUM SULFIDE CRYSTALS

G. F. Heinrich, Capt: USAF AD 418558

Air University USAF, Wright-Patterson AFB, Ohio, August 1963

Velocity and attenuation of pulsed, ultrasonic stress waves in 5 cadmium sulfide crystals, 3 of which were "tap effect" crystals, were measured at frequencies of 5 and 10 mc/sec, at temperatures of 77°K and 300°K. Velocity and attenuation measurements were taken while crystal was irradiated with different, discrete, wavelength light in directions parallel to and perpendicular to the C-axis. Attenuation of stress waves was proportional to the conductivity when the stress waves were propagated parallel to C-axis at 300°K. Attenuation wasn't a function of conductivity when stress waves were propagated perpendicular to C-axis. Attenuation was greater at 77°K than attenuation at room temperature. 300°K attenuation results on all 3 "tap effects" crystals were similar to the results that Truell and Nine obtained on their so-called type "B" cadmium sulfide crystals.

3760 ULTRASONIC METHODS IN THE STUDY OF DEFORMATION IN SINGLE CRYSTALS
B. Chick, A. Hikata, G. Anderson, C. Elbaum, R. Truell AD 606759
Brown University, Providence, R. I. N65-13435
Wright-Patterson Air Force Contract No. AF 33 (657)8324.
Rpt. No. ML-TDR-64-34, March 1964

The purpose of this investigation is that of understanding the physical changes which occur in aluminum and in certain ionic crystals during and after deformation. The investigation involves the study of imperfection behavior generally, and specifically the interaction of point defects with moving and vibrating dislocations, as well as the contribution of dislocations to the anharmonic characteristics of solids. Experiments were carried out on the recovery of ultrasonic attenuation following plastic deformation and as a function of plastic strain.

3779 GRAIN SIZE MEASUREMENTS IN URANIUM BY USE OF ULTRASONICS
H. L. Dunegan
University of California, Livermore, California
Materials Evaluation, August 1964

Ultrasonic attenuation and velocity measurements were made on polycrystalline uranium specimens of varying grain size. The major contribution to the attenuation is shown to be due to a scattering mechanism created by the anisotropic grain orientation. It is also shown that this attenuation is very sensitive to small changes in grain diameter, and thus can be used as a quantitative nondestructive measurement of grain size. A description is given of the specimens, mechanical fixturing, and electronic instrumentation for making these measurements. Some basic theory on the attenuation of sound is also included.

3822 STUDY OF THE ELECTRONIC PROPERTIES OF METALS BY ULTRASONICS
J. D. Gavenda
University of Texas
Proc. of Symposium on Physics and NDT Testing, October 1962
Southwest Research Institute, San Antonia, Texas

It is now realized that ultrasonic attenuation in pure metals at low temperatures is caused primarily by the interaction of conduction electrons with the lattice and can be measured directly. This paper outlines the technique and illustrates its use with specific metals.

3842 ULTRASONICS, A SOLID STATE RESEARCH TOOL
N. G. Einspruch
Texas Instruments Incorporated
Proc. of the Symposium on Physics and NDT Testing, October 1963
Southwest Research Institute, San Antonio, Texas

A review of the use of ultrasonics in elucidating the physical properties of metals (normal conductors, superconductors), magnetic materials, semiconductors and insulators is presented in terms of the interactions observable in ultrasonic velocity and attenuation measurements. Experiments on electron-phonon interactions, and defect-phonon interactions are discussed in detail.

3854 RESIDUAL STRESS STUDIES IN FERROMAGNETIC MATERIALS IN ULTRASONICS
D. Mills and W. J. Bratina
Ontario Research Foundation and University of Toronto
Proc. of the Symposium on Physics and NDT Testing, October 1963
Southwest Research Institute, San Antonio, Texas

The internal stresses in ferromagnetic materials were studied by means of magneto-mechanical component of ultrasonic wave attenuation. The approach is based on a very marked difference in attenuation characteristics of an annealed and cold worked material. The latter was found to exhibit a characteristic attenuation maximum at a definite value of applied stress or magnetic field. The attenuation is highly sensitive to the presence of internal stress, and the magnitude of stress is related to the position of the maximum. The structure and mobility of the domain walls are affected by the changes in dislocation density, and associated magneto-mechanical losses are expected to change accordingly. The maximum in the damping observed in cold worked ferromagnetic materials at low and kilocycle frequencies are briefly discussed.

3885 ULTRASONIC NONDESTRUCTIVE TEST FOR THE DETECTION OF IMPROPER HEAT TREATMENT OF STEEL
E. P. Papadakis
Bell Telephone Labs., Allentown, Pa.
Materials Evaluation, March 1965

An ultrasonic test is proposed to determine whether the cycle of hardening and tempering steel parts has been carried through properly. The test depends upon the changes in ultrasonic attenuation occurring upon change of the grain size and microstructure of steel. Failure to heat sufficiently to reach the minimum austenitizing temperature may leave the attenuation 100 times higher than in tempered martensite. The ultrasonic attenuation test method samples the body of the part, not just its surface. This ultrasonic method is compatible with automated processes.

3913 DETERMINATION OF EFFECT OF MATERIALS AND PROCESS VARIABLES ON FILAMENT WOUND STRUCTURES
B. E. Chester
Aerojet General Corporation, Azusa, California
U. S. Naval Applied Science Lab, Contract No. N140 (131)-75687B (X)
Progress Rpt. No. 0827-02-2 (quarterly)

Sixteen 3.0 inch I.D, by 6.0 inch long glass composite test specimens having 0.375 inch thick walls were fabricated using machine wrapped filaments. Ultrasonic data, void content, calculations, and microphotographs from the test specimens tend to support the theory established on other programs that a high ultrasonic attenuation indicates high void content.

3934 ULTRASONIC DETECTION OF CHANGES IN THE ELASTIC PROPERTIES OF A 70-30 IRON-NICKEL ALLOY UPON HEAT TREATMENT
E. P. Papadakis and E. L. Reed
Journal of Applied Physics, Vol. 32, April 1961, p. 682-687

Ultrasonic attenuation and velocity measurements by the pulse echo method after various steps in their transformation from austensite to martensite. Attenuation from Rayleigh scattering decreased, while that from elastic hysteresis increased as the transformation proceeded. Presence of small martensite platelets in the grains reduced anisotropy of elastic constants of the grains, thus reducing the Rayleigh scattering. Increase in hysteresis parallels the increase the residual strain and the increase in grain boundary material attending the transformation.

3956 ULTRASONIC ATTENUATION IN METALS
R. W. Morse
Paper from "Seventh International Conference on Low Temperature Physics, Proceedings". University of Toronto Press, Canada, 1961, p. 233-239

Review of experiments on the interaction between ultrasonics and electrons in metals at low temperature by observation of an attenuation of ultrasonic waves by electronic which occurs when the electron free path is comparable to or greater in size than the ultrasonic wave length. Application of attenuation measurements to determination of Fermi surface, superconducting energy gap, anisotropy and possibility of an acoustic factor in Au, Ag, Sn and Cu single crystals at 1.2°K. 9 ref.

4012 DAMPING MEASUREMENTS ON CAST STEEL WITH A SOUND-IMPULSE APPARATUS
S. Kippa
Giessereitechnik (German), Vol. 9, June 1963
Materials Evaluation, October 1963

Comparative measurements of the sound attenuation in annealed and nonannealed specimens of GS 38-9 Cast steel of given impulse tester, in order to develop a simple nondestructive test for distinguishing between annealed and nonannealed steels.

4015 ULTRASONIC INTERNAL CONICAL REFRACTION IN ROCKSALT AND CALCITE
E. P. Papadakis
Journal of Applied Physics, Vol. 34, August 1963
Materials Evaluation, October 1964

Evidence for the existance of rocksalt and calcite single crystals was obtained by observing the behavior of shear waves along one of the axes of threefold symmetry in each crystal. A method of selective absorption was used in conjunction with pulse-echo ultrasonic attenuation measurements. Absorbing materials were pasted at various spots on the bottom of the specimen opposite the transducer to mop the energy density in the wave. Positions of maximum flux coincided with predictions when the shear wave was not perturbed by nusorientation-induced ultrasonic double refraction.

4097 ULTRASONIC ATTENUATION IN SUPERCONDUCTORS CONTAINING MAGNETIC IMPURITIES
L. P. Kadanoff, I. I. Falko
University of Illinois, Urbana, Ill. 13 July 1964
The Physical Review Vol. 136-30 Nov. 1964

In this calculation several electronic time-dependent correlation functions are evaluated, and these functions are then used to evaluate the attenuation. In the limit of low sound frequencies, coefficients are expressed in terms of a single energy integral. Attenuation in the limit of low temperatures is evaluated for superconductors.

4098 ULTRASONIC ATTENUATION IN METALS IN THE FLUID-DYNAMIC APPROXIMATION
L. H. Hall
University of California, Santa Barbara, California.
The Physical Review, Vol. 136, No. 4a, Nov. 1964

Studies are undertaken on low-frequency range which makes contact with the transport-theory formalism of classical gares. "Fluid"-dynamic equations for metal are presented. Acoustic attenuation coefficient for a longitudinal wave is outlined and thermal and diffusion effects are explicit.

4109 COMPLEMENTARY EQUIPMENT TO ULTRASONIC FLAW DETECTORS ALLOWING ATTENUATION MEASUREMENTS IN THE FREQUENCY RANGE 10-100 Mc/s
H. Wehr
Polish Academy of Sciences, Warsaw, Poland
Proc. of the Fourth International Conf. on NDT, published by Butterworth Inc., Washington, D. C., September 1963, p. 162-163

A simple and compact unit is described for generating, transmitting, and receiving ultrasonic pulses in the frequency range of 10-100 Mc/s. It permits the measurement of velocity and attenuation of ultrasonic waves in liquid and solids.

4110 DETERMINATION OF TENSILE STRENGTH OF CAST IRON BY ULTRASONICS
J. A. F. Jarvis
Internations Meehanite Metal Co., Epson, Surrey
Proc. of the Fourth International Conf. on NDT, published by Butterworth Inc., Washington, D. C., September 1963, p. 173-175

This article briefly covers the use of the relationship between the velocity of the ultrasonic energy and the tensile strength of cast iron. The absorption or attenuation technique is used by comparing a known standard specimen with those parts undergoing tests. This simple technique has been used on hundreds of thousands of castings without customer refect for low tensile.

4112 QUALITY CONTROL OF STEEL PRODUCTS BY DETERMINATION OF SOUND ATTENUATION
E. Krainer
Gebr. Bohler & Co., Kapfenberg, Austria
Proc. of the Fourth International Conf. on NDT, published by Butterworth Inc., Washington, D. C., September 1963, p. 180-184

The field of nondestructive testing is not limited to flaw detection but also includes evaluation of physical properties of metals. Determination of resistivity, permeability, etc. are already well known methods. Ultrasonic attenuation and its evaluation of the physical properties of steel products is discussed in this report.

4114 ULTRASONIC ATTENUATION DURING CYCLIC STRAINING
Z. Pawlowski
Polish Academy of Science, Warsaw, Poland
Proc. of the Fourth International Conf. on NDT, published by Butterworth Inc., Washington, D. C., September 1963, p. 192-195

This paper describes the attempt made to connect the parameters characterizing the attenuation of ultrasonic waves with certain characteristics of the fatigue properties of metals. The knowledge of the changes in internal friction and their connection with an appropriate stage of fatigue may become a basic for nondestructive tests to eliminate the risk of failure due to fatigue.

4154 ELASTIC PROPERTIES OF POLYCRYSTALLINE TUNGSTEN AT ELEVATED TEMPERATURES
B. T. Bernstein N62-16321
Union Carbide Research Inst., Tarrytown, N. Y.,
In its Research on Physical and Chemical Principles Affecting High Temperature Materials for Rocket Nozzles.
Qtly. Rpt. July to September 1962, Repr. from J. Appl. Phys., Vol. 33, No. 6, June 1962

An ultrasonic pulse-echo technique was used to measure velocities of compressional and shear waves at 10 mc in polycrystalline swaged tungsten. Ultrasonic velocities were used to calculate the elastic moduli. Results are presented for the temperature dependence of the elastic properties of the tungsten at elevated temperatures. Shear velocity and modulus decrease smoothly with increasing temperature, except in the range 600° to 800°C where the decrease is more rapid. Relative attenuation of echo amplitude also shows an anomaly in the temperature range 650° to 900°C. Above 1280° shear wave attenuation is so great that measurements are not possible. The compressional velocity was also shown to decrease smoothly with increasing temperature. Measurements on single crystals and chemically analyzed high purity polycrystalline tungsten are planned in order to help resolve the damping mechanism.

4180 ULTRASONIC SPECTROSCOPY OF STEEL
O. Gericke AD 614 113
U. S. Army Materials Research Agency, Watertown, Mass.
AMRA TR 64-44, December 1964.

An electronic instrument has been developed which makes it possible to obtain the ultrasonic attenuation spectrum of a solid material. The spectroscope employs the ultrasonic pulse-echo test technique and is equipped with a single ultrasonic transducer which is used for both transmission and reception of ultrasonic signals. The ultrasonic spectroscope has been applied to examine microstructures of steel specimens differently heat treated to produce grain size variations. Experimental results indicate that the amplitude distribution in the ultrasonic spectrum is strongly influenced by specimen microstructure. It is possible to discriminate between grain sizes varying from 2 to 8 (ASTM Scale).

4206 THE CORRELATION OF DESTRUCTIVE AND NONDESTRUCTIVE TESTING OF HEAVY STEEL CASTINGS WITH PARTICULAR REFERENCE TO ULTRASONIC EXAMINATION
J. D. Lavender
British Steel Casting Research Association, Iron & Steel, June 1964.
Iron & Steel Prize 1964. Presentation, Sheffield Metallurgical and Engineering Association

Results obtained from this report show that the ultrasonic detection method has a far greater sensitivity to minor inhomogeneities in cast steel than does high resolution X-ray or gamma ray techniques. Correlation between ultrasonic attenuation measurements and mechanical data is included.

4269 THE ULTRASONIC ATTENUATION IN METALS. METHOD OF MEASURING BY PULSE TECHNIQUE AND ANALYSIS OF THE EXTERNAL LOSS DUE TO COUPLING
M. Robba
Alluminio, Vol. 32, No. 9, September 1963, p. 421-431

Measurement of the ultrasonic attenuation in Ergal 65 and SAP Al alloys by pulse technique, by direct coupling and by water immersion. It is found that the energy loss increases due to the action of the coupling medium on the impulse reflection.

4273 FATIGUE LIMIT AND ITS DISPERSION
Z. Pawlowski
Przegl Spawalnictwa, Vol. 16, No. 7-8, 1964, p. 161-173

Examples given for the statistical estimation of life and strength distributions in the region of fatigue and endurance limit of Al-Mg-Si alloy and gray cast iron. Results of Probit, Staircase and Cocati methods compared. Results obtained indicate that the cumulative damage differs from unity. The proper value of the cumulative damage was determined on the basis of measurements of ultrasonic waves attenuation during cyclic straining.

4277 TEMPERATURE DEPENDENCE OF THE ULTRASONIC ATTENUATION IN GERMANIUM
B. L. Miller
Physical Review, Vol. 132, No. 6, December 15, 1963, p. 2477-2483

The ultrasonic attenuation in Ge is measured as a function of temperature from 20° to 300°K, and at frequencies of 4 to 132 Mc/sec. The measurements are made using the pulse echo technique with longitudinal sound pulses along the (111) direction.

4308 ULTRASONIC INSPECTION OF SPOT-WELDED ALUMINIUM ALLOYS
I. V. Vavulo
Welding Production, No. 7, July 1962, p. 63-66.

Effectiveness of ultrasonic inspection for detecting lack of fusion in spot welds in D16, V95, and AMg^{6}Al alloys. Attenuation of ultrasonic vibration in these alloys as affected by increased frequency.

4326 DEVELOPMENT OF NONDESTRUCTIVE TESTING INSTRUMENTATION FOR REACTOR PRESSURE VESSELS
W. J. McGonnagle
Southwest Research Inst., San Antonio, Texas, July 15, 1963

An investigation is being conducted to develop a nondestructive testing technique for measuring the shift in the nil ductility transition temperature of A-212 Grade B steel. A correlation was found between the amount of cold working and magnetoabsorption, thermal conductivity, and ultrasonic attenuation. Magnetoabsorption measurements as a function of cold work in A-212 Grade B steel appear to be very promising. The measurement of the ultrasonic attenuation coefficient in cold work material by a through transmission technique showed a relationship between cold work and the attenuation coefficient. The thermal comparator shows applicability to measuring the level of cold work in A-212 Grade B steel. It appears that all three of the techniques evaluated have potential for determining the level of cold work in A-212 Grade B steel.

4341 ULTRASONIC STUDY OF THE CUBIC-TETRAGONAL PHASE CHANGE AND THE CURIE TEMPERATURE OF SINGLE CRYSTAL $SrTiO_3$
R. S. Krogstad and R. W. Moss
Boeing Scientific Research Labs., Seattle, March 1962, 12 p.

An investigation is described in which attenuation and sound velocity as a function of temperature were measured over a frequency range 10 to 150 mc/sec on single crystal specimens of $SrTiO_3$ along three principal crystallographic directions at room temperature to that of liquid He. It was found that ultrasonic attenuation in $SrTiO_3$ exhibits two dominant maxima; one starting at 110 degrees K which is attributed to the scattering of phonons at the interfaces between cubic and tetragonal domains which coexists in a narrow temperature range below this point, and a second below about 48 degrees K which is ascribed to ferroelectric dielectric losses.

4365 ULTRASONIC ATTENUATION IN SUPERCONDUCTING LEAD
R. E. Love and R. W. Shaw
Reviews of Modern Physics, Vol. 36, No. 1, Pt. 1, January 1964, p. 260-263

Measurement of the ultrasonic attenuation of Pb in various crystallographic directions over the 2° to 20°K temperature range both in magnetic field and zero field to determine the superconducting energy gap.

4436 ACUSTO-ELASTIC AND ACUSTO-PLASTIC DEFORMATIONS IN ROLLED Cr-Ni-Mo STEEL PIPES
J. Pirs
Rudarsko-Metalurski Zbornik, No. 2, 1964, p. 137-156 (in Solvenian)

The plastic deformation phenomena in Cr-Ni-Mo steel pipes are investigated by ultrasonic methods. It is evident from results obtained that stresses caused by deformation affect ultrasonic attenuation and sound propagation within the pipe. Data can be used to calculate the degree of deformation and stresses created by such deformations.

4454 MEASUREMENT OF CHILL DEPTH ON CAST IRON TEST PIECES AND ROLLS
J. L. Smith and A. G. Fuller
BCIRA Journal, Vol. 12, No. 3, May 1964, p. 319-326

A technique for estimating chill depth in chilled test castings and iron rolls by measuring the delay between introduction of ultrasonic energy into the casting and the first echo occurring as a result of attenuation of the signal in the mottled zone. Accuracy is greatest when the transition from the chilled zone to the gray core is sharp.

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All descriptors listed in alphabetical order pertain to the information contained in the report or item that is identified by the AMRA number following the descriptor. This journal is for Ultrasonic Attenuation literature and every item in the journal contains some aspect of the subject. A complete breakdown of the subject by descriptors was deemed necessary in order to make the journal more useful.

Reviewers need only to refer to the item numbers which apply to the particular descriptors of interest and turn to the abstract applicable to those referenced numbers.

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