

## Abstracts of Technical Articles by Bell System Authors

*Gross-linkage of Linear Polyesters by Free Radicals.*<sup>1</sup> W. O. BAKER. Reactions fundamental to the use of the new low pressure laminating or casting resins have been studied. The striking property of these plastics, which are usually based on some polyester and a vinyl monomer, is their rapid and easy curing, leading to unique ease of fabrication. This curing, the formation of a permanent three-dimensional polymer network, or gel, is achieved by reaction with a source of free radicals, such as from an organic peroxide. These agents cause polymerization of the vinyl monomer, as was previously understood, but they also seem to incorporate the polyester into the network, even if the polyester contains little or no unsaturation.

Investigation of a series of simple polyesters, the polyundecanoates, showed that free radicals, such as come from the decomposition of benzoyl peroxide, could cross-link or gel the linear, saturated, chains. Apparently the hydrogen atoms in methylene groups next to polar groups like the carbonyl, i.e., the  $\alpha$ -hydrogens, are removed by the free radicals. The resulting chain radical attacks an adjacent chain, and a cross-link is formed. The effects of cross-links thus produced on solubility, dilute solution viscosity, melt viscosity and, finally, stress relaxation of the cured solid were examined. Probably the similar activity of  $\alpha$ -hydrogen atoms is important in the chemical aging or weathering of plastics and rubbers. It is likewise significant for the vulcanization of many synthetic rubbers.

*Rubberlike Products from Linear Polyesters.*<sup>2</sup> B. S. BIGGS, R. H. ERICKSON and C. S. FULLER. The polymers which result from the condensation of dibasic acids with propylene glycol are viscous gums which can be vulcanized to rubberlike products. In the unpigmented condition these rubbers are quite weak, but when reinforced with suitable pigments their strength and elongation compare favorably with other synthetic rubbers. Because polyesters of known structure and molecular weight can be easily synthesized, these polymers are useful for the study of the relations between structure and properties in rubberlike materials in general. Factors affecting tensile strength, oil resistance, brittle temperature, and stability are discussed.

*Pulse Code Modulation.*<sup>3</sup> H. S. BLACK and J. O. EDSON. A radically new modulation technique for multichannel telephony has been developed which involves the conversion of speech waves into coded pulses. This new tech-

<sup>1</sup> *Jour. Amer. Chemical Soc.*, May 1947.

<sup>2</sup> *Indus. & Engg. Chem.*, September 1947.

<sup>3</sup> *Telephony*, August 30, 1947.

nique is called Pulse Code Modulation or simply PCM. An eight-channel system embodying these principles was developed and produced in portable form for field operation. Other work carried on simultaneously by W. M. Goodall (see B. S. T. J., July 1947) resulted in the development of an experimental system using a different method of coding.

In carrying out this new type of modulation, the speech wave applied to each channel is, in effect, transmitted sample by sample, and each sample is represented by a multi-unit code employing on-or-off pulses, hence the term PCM.

This method appears to have exceptional possibilities from the standpoint of freedom from interference. Its full significance in connection with future radio and wire transmission may take some time to reveal.

*Stereoscopic Drawings of Crystal Structures.*<sup>4</sup> W. L. BOND. A method is presented for getting stereoscopic pairs of atomic structure views given the coordinates of the atoms and cell constants.

*Properties of Liquids at High Sound Pressure.*<sup>5</sup> H. B. BRIGGS, J. B. JOHNSON and W. P. MASON. When sound of high amplitude is transmitted into a liquid by means of a mechanical driving device, the ultimate limitation to the power that can be transferred is cavitation or breakdown of the liquid under high internal stresses. A study of cavitation has resulted in establishing the following results. Under steady-state conditions, light liquids filled with air cavitate when the negative acoustic pressure reaches the atmospheric pressure. When liquids are degassed, their natural cohesive pressure becomes effective and they will withstand a negative acoustic pressure. It is found that the total negative pressure required to cause cavitation is equal to the sum of the cohesive pressure—tensile strength—and the ambient pressure. Viscous liquids have a higher cohesive pressure and a proportionality has been established between the logarithm of the viscosity and the cohesive pressure. The amount of power that a liquid can withstand increases markedly as the pulse length is shortened.

An explanation of these phenomena is attempted on the basis of Eyring's theory of viscosity, plasticity and diffusion. On this theory natural holes exist in the liquid into which molecules can jump, leaving holes behind them. A jump occurs when the molecule has accumulated enough heat energy to surmount an activation potential barrier of energy value  $E_0$ . Cavitation appears to be the result of coalescing of the natural holes in the negative pressure phase of the cycle. Since a molecule has to jump from a hole in order that this can coalesce with another hole, the cavitation pressure is proportional to the activation energy which in turn is proportional to the log-

<sup>4</sup> *The American Mineralogist*, July-August 1947.

<sup>5</sup> *Jour. Acous. Soc. Amer.*, July 1947.

arithm of the viscosity. The increased power-transmitting capacity for short pulse lengths is a result of the finite time taken for the small holes to grow in size to a large enough hole to cause rupture of the liquid.

*Modulation in Communication.*<sup>6</sup> F. A. COWAN. The fundamentals involved in introducing signals into one medium and transmitting them through another are simplified in this review, so that the relationships between the many varieties of modulations attempted or in contemporary use are formed into a cohesive whole.

*Air-borne Magnetometers.*<sup>7</sup> E. P. FELCH,\* W. J. MEANS,\* T. SLONCZEWSKI,\* L. G. PARRATT, L. H. RUMBAUGH and A. J. TICKNER.\* Developed under the impetus of the submarine menace of World War II, the air-borne magnetometer has found many peacetime uses. Navy airplanes equipped with magnetometers for exploration of Antarctica were used in the recent United States Navy expedition. An expedition now is studying the Aleutian Alaskan volcanos and the Aleutian submarine trench. From there it will proceed to Hawaii and Bikini.

*The Generation of Centimeter Waves.*<sup>8</sup> H. D. HAGSTRUM. The electronic devices used most extensively, recently, for the generation of centimeter waves are discussed. The physical form, operating capabilities, and the basic physical principles of operation of the triode, velocity-variation, and magnetron oscillators are presented. An attempt is made to show how these oscillators are related to one another. For a variety of reasons, particular emphasis is placed on the magnetron oscillator.

*Selective Demodulation.*<sup>9</sup> DONALD B. HARRIS. A method of demodulation is proposed in which the output current of the demodulator is a linear function of the input voltage, while at the same time provision is made for producing the necessary product terms which will result in demodulation. Demodulation is brought about by integrating the product of the instantaneous value of the modulated wave by the instantaneous value of a wave having the same frequency and phase as the carrier. Where this method of demodulation is used it is proposed that two carriers in quadrature on the same frequency may be employed, reducing the bandwidth to that required for single-sideband transmission.

It is suggested that the required linear demodulation characteristics may be obtained through the use of "electron-coupled" demodulators. Theoretical considerations indicate that, when demodulation of this type is employed, selectivity ahead of the demodulator may be dispensed with, the

<sup>6</sup> *Elec. Engg.*, September 1947.

<sup>7</sup> *Elec. Engg.*, July 1947.

\* *Of the Bell System.*

<sup>8</sup> *Proc. I. R. E.*, June 1947.

<sup>9</sup> *Proc. I. R. E.*, June 1947.

signal-to-noise ratio is improved, greater economy of spectrum space is obtained, the number of tubes required is materially reduced through the use of a common intermediate-frequency amplifier for a number of channels, and any impairment due to the instability of the carrier or oscillator frequency is reduced.

As an example of the possible application of the principles outlined, a hypothetical eight-channel transmission system is described.

*The Physical Significance of Birkhoff's Gravitational Equations.*<sup>10</sup> HERBERT E. IVES. Birkhoff's gravitational equations are put in terms of  $dt$  in place of the local time  $ds$  used by him. The transformed equations show that Lorentzian mass has been used, and to the Newtonian attractive force is added a force normal to the direction of motion,  $v^2/c^2$  times the component of the gravitational force normal to the motion.

*Attenuation and Scattering of High-Frequency Sound Waves in Metals and Glasses.*<sup>11</sup> W. P. MASON and H. J. MCSKIMIN. By using a pulse method, attenuation and velocity measurements have been made for aluminum and glass rods in the frequency range from 2 to 15 megacycles. The sound pulses are generated by crystals waxed to the surface of the rod. This wax joint limits the band width of the transmitted pulse and measurements are made using long pulses which approach steady state conditions. The reflected pulses show evidence of several normal modes which can be minimized by using specially shaped electrodes. Longitudinal waves show delayed pulses of smaller magnitude that are caused by the longitudinal wave breaking up into reflected longitudinal and shear waves at the boundary. This effect is small if the diameter of the rod is 20 wave-lengths or more.

The measured losses for aluminum rods show a component proportional to the frequency and another component proportional to the fourth power of the frequency. The first component is the hysteresis loss found for most solid materials. The component proportional to the fourth power of the frequency is caused by Rayleigh scattering losses which are the result of differences in the elastic constants between adjacent grains caused by changes in orientation. Calculated scattering losses agree quite well with the measured values. The fourth-power scattering law holds quite well until the grain size is equal to one-third of a wave-length. For higher frequencies the scattering loss increases more nearly with the square of the frequency. Glasses and fused quartz have a loss directly proportional to the frequency, showing that any irregularities must be of very small size.

*The Growth of Auditory Sensation.*<sup>12</sup> W. A. MUNSON. The integration of sensation with respect to time was studied experimentally by means of tones

<sup>10</sup> *Phys. Rev.*, August 1, 1947.

<sup>11</sup> *Jour. Acous. Soc. Amer.*, May 1947.

<sup>12</sup> *Jour. Acous. Soc. Amer.*, July 1947.

of short duration. Loudness tests were made on sounds persisting from 0.005 to 0.2 second and covering a wide range of levels. The observed increase in magnitude of a sensation as the duration time is increased is attributed to the integration characteristic of the central nervous system, and an equivalent electrical circuit is derived. The circuit analogy is then used in the computation of loudness as a function of the duration of the stimulus.

*The Physics of Electronic Semiconductors.*<sup>13</sup> G. L. PEARSON. The band theory of solids is capable of explaining such fundamental properties of electronic semiconductors as the dependency of specific resistance on impurity content, the negative temperature coefficient of resistance, the sign of the Hall and thermoelectric effects, and the direction of rectification. Measurements of the specific resistance and the Hall constant enable the calculation of density, mobility, and mean free path of the electric carriers as a function of temperature and impurity.

*Automatic Frequency Control of Microwave Oscillators.*<sup>14</sup> VINCENT C. RIDEOUT. A method for the automatic frequency control of any type of tunable microwave oscillator is described. In this method a servomechanism is used which includes a wave-guide discriminator circuit, a mercury-contact relay, a 60-cycle amplifier, and a small two-phase induction motor.

Tests made on a preliminary model of a circuit of this type used with a 4000-megacycle oscillator showed that a stability of one part in 50,000 was obtainable. The manner in which such a control system may be used in a microwave repeater is described.

*Proposed Method of Rating Microphones and Loudspeakers for Systems Use.*<sup>15</sup> FRANK F. ROMANOW and MELVILLE S. HAWLEY. Proposed, is a method of rating microphones and loudspeakers whereby the over-all performance of a sound system may be determined by adding together the microphone and loudspeaker ratings and the gain of the interconnecting network. This sum gives the performance quite accurately for most systems. However, in some combinations of elements correction terms must be added. The formulas for these correction terms are derived.

The proposed microphone and loudspeaker ratings have the additional usefulness of being in a form which permits the comparison of instruments of different impedances.

*Sulfur Linkage in Vulcanized Rubber.*<sup>16</sup> MILTON L. SELKER and A. R. KEMP. The reaction of 2-methyl-2-butene with sulfur at 141.6°C. was studied. Reaction time and concentration paralleled those common in

<sup>13</sup> *Elec. Engg.*, July 1947.

<sup>14</sup> *Proc. I. R. E.*, August 1947.

<sup>15</sup> *Proc. I. R. E., Waves and Electrons Section*, September 1947.

<sup>16</sup> *Indus. & Engg. Chem.*, July 1947.

rubber-sulfur vulcanization. The results offer further insight into the vulcanization problem. The products of the reaction are liquids of the polysulfide type  $R-S_x-R$ , where  $x$  varies from 2 to 6 and  $R$  is an alkyl or alkenyl group and two solids ( $C_8H_8S_3$  and a higher homolog). The polysulfides appear to be somewhat richer in hydrogen than is expected from reaction of two  $C_8H_{10}$  molecules, whereas the solids are hydrogen-poor. The structure of an acid anhydride in the sulfur system showing thione-thiol tautomerism is proposed for  $C_8H_6S_3$ , which is therefore 2,5-dithione-3-methyltetrahydrothiophene. The color changes with reaction time, from yellow to red to black, parallel those of rubber-sulfur vulcanizates. As in rubber-sulfur vulcanization the sulfur reaction rate is directly proportional to time, although the absolute rate is twice that in the polymer system. Starting with equal mole quantities of olefin and sulfur, there is a considerable amount of unreacted olefin in the system when all of the sulfur has reacted. The shorter the reaction time, the higher the value of  $x$  in the polysulfide  $R-S_x-R$  and the larger the percentage of residues  $R$  that are saturated.

*On Hearing in Water vs. Hearing in Air.*<sup>17</sup> L. J. SIVIAN. The paper deals with the ability of a submerged listener to hear sounds generated in the air above him, compared with their audibility when his head projects above the water. In a theoretical discussion it is shown that at 1000 c.p.s. a loss of the order of 45-55 db might be expected in the in-water audibility relative to the in-air value. This involves a number of assumptions, e.g., that there is no appreciable noise created by the listener's propulsion, and that the effect of hydrostatic pressure unbalance on the eardrum is negligible. A few measurements made at 1000 c.p.s. and 3000 c.p.s. yielded values which are not at variance with the theoretical analysis.

*Cathode Phase Inverter Design.*<sup>18</sup> C. W. VADERSEN. Part I of this paper covers the general analysis of the cathode coupled phase inverter and develops formulae that enable the designer to compute circuit elements with good accuracy. The theory developed shows that degeneration exists only in the driven side of the amplifier and is limited to 6 decibels. Balance is discussed in terms of the tube parameters and external resistances, its being shown that considerable stability is attainable. A form of the inverter in which the power output stage utilizes a transformer with an unbalanced plate winding is presented. This is shown to give a true power balance in a manner analogous to the unbalanced plate resistor form of the voltage amplifying inverter.

Part II presents a graph of the general design equations and illustrates its use with several working examples.

<sup>17</sup> *Jour. Acous. Soc. Amer.*, May 1947.

<sup>18</sup> *Audio Engineering*, June and July 1947.