

Li(Co,Al)O₂ Cathode Materials Reduce Cost of Lithium Batteries

The main obstacle to the widespread use of electric cars is the lack of a suitable battery due to the lack of materials to make it cheap, light, and powerful. Responding to the materials needs, a research team at the Massachusetts Institute of Technology has developed a battery in which the cathode is made from a mixture of lithium aluminum oxide and lithium cobalt oxide, as reported in the April 16 issue of *Nature*. The team first predicted the composition of a promising material through computer models, then produced and tested it.

Currently the key cathode material is a compound of lithium, cobalt, and oxygen. However, cobalt is extremely expensive, so these batteries are used only in small devices like cellular phones and laptop computers. According to Donald R. Sadoway, Professor of Materials Chemistry and MacVicar Faculty Fellow at MIT, a lithium battery for an electric car would cost about \$20,000 and enable the vehicle to travel only about 120 miles. The researchers' computer calculations showed that aluminum, which is cheap and light, or other metals in the same class could be used in place of cobalt. The computer model further predicted that a compound containing aluminum would generate a higher cell voltage than the

conventional cobalt version. The predicted compound, lithium aluminum oxide, however, in its pure form does not conduct electrons. Sadoway said, "In a cathode, this material would be all voltage and no current."

Yet-Ming Chiang, Kyocera Professor of Ceramics at MIT, said that adding back some cobalt would solve the conductivity problem; that is, a mixture of lithium aluminum oxide and lithium cobalt oxide should meet the requirements. The researchers experimented with samples containing different proportions of aluminum and cobalt (LiAl_yCo_{1-y}O₂). They prepared the cathodes by mixing the oxide powder with carbon black and potting the mixture in a binder of poly(vinylidene fluoride). As reported in the article, "Pellets weighing 10–35 mg and measuring 1.0 cm² in surface area were formed by pressing at 360 MPa. These were dried at 140°C under primary vacuum for 24 h." The LiAl_{0.25}Co_{0.75}O₂/Li cell, limited by the stability of the electrolyte, showed charges of 4.4 V. As reported in the article, the initial charge and discharge capacity were 120 and 90 mA h g⁻¹, respectively, and on the sixth cycle the charge and discharge capacity were ~90 and 80 mA h g⁻¹. The researchers believe that more capacity could be found at higher potential.

Ultrathin Polyelectrolyte Films Fabricated in Gas Phase

The Langmuir-Blodgett (LB) technique offers the possibility to fabricate smooth, highly ordered ultrathin films with monolayer by monolayer control of thickness. Examples of pure materials commonly used for multilayer fabrication with this technique include fatty acids, phospholipids, hairy-rod polymers, and some polymers with long side chains. However, not all molecules, such as water soluble polymers, can be processed into single component multilayers by this technique. In order to overcome this limitation and obtain hydrophilic surfaces with high carboxylic acid densities desirable for models of superabsorbing polymers, bioadsorption studies, and as precursors for subsequent chemical modification, Alan Esker, Christoph Mengel, and Gerhard Wegner from the Max Planck Institute for Polymer Research, Mainz, Germany, applied another approach, as reported in the May 8 issue of *Science*. Post transfer modification of preformed LB-films of poly(tertbutylmethacrylate) (PtBMA) and poly(tert-butyl acrylate) (PtBA) yields polyelectrolyte films for polymethacrylic acid (PMAA) and polyacrylic acid (PAA),

respectively, in the gas phase. By exposing the precursor films to gaseous hydrochloric acid (60°C, 6 h), isobutene is eliminated. This converts the ester groups to carboxylic acid moieties, and hence generates polyelectrolytes with different surface properties and chemical reactivity.

The first step of this approach is the formation of stable monolayers at the air/water interface, thereby trapping the molecules in two-dimensional conformations. For PtBMA and PtBA, this behavior was already well-known through monolayer studies of their isotherms, surface rheology, and dynamics. This is followed by LB-transfer of the materials to hydrophobic silicon wafers, in which one monolayer is transferred on each up and down stroke of the substrate. This has been confirmed by x-ray reflectivity. The most significant difference between the two systems is the presence of a so-called Bragg peak for PtBA films indicating a double layer structure. This is never seen for PtBMA which suggests that the methyl groups along the backbone alter the packing characteristics. Thickness per layer data from x-ray reflectivity and the surface concentration during transfer can be used to calculate PtBMA's film density, which is in agreement with the bulk value. In contrast, PtBA's calculated density is significantly lower than the bulk value. This implies that PtBMA has similar packing at both the air/water interface and in the bulk, whereas PtBA possessing greater flexibility can assume a conformation with all of the hydrophobic groups oriented away from the interface.

Subsequent hydrolysis of the PtBMA and PtBA films does not significantly increase their surface roughnesses. The linear relationship between the thickness of PMAA and PAA and the number of layers originally transferred, along with the absence of dewetting, suggest that although the double layer structure is destroyed, the layered structure may remain (i.e., two-dimensional-conformations are retained). In addition to x-ray reflectivity, ir-spectroscopy was used to confirm the transformation of the tert-butyl ester groups to the desired carboxylic acids. Clean shifts of the carbonyl and C-O stretch, along with the growth of a broad hydroxyl stretch are consistent with the existence of PMAA primarily as acid dimer.

For future applications, networks of these materials are desired. To test the feasibility of this approach, isopentylcellulose cinnamate was mixed with bifunctional-vinylbenzyl-terminated PtBMA. Subsequent photo-induced cross-linking left insoluble network structures which could

Review Articles

The July 1998 issue of *Reviews of Modern Physics* features the following review articles: S. Chu, "Nobel Lecture: The Manipulation of Neutral Particles"; C. Cohen-Tannoudji, "Nobel Lecture: Manipulating Atoms with Photons"; W.D. Phillips, "Nobel Lecture: Laser Cooling and Trapping of Neutral Atoms"; M.A. Kastner, R.J. Birgenau, G. Shirane, and Y. Endoh, "Magnetic, Transport, and Optical Properties of Monolayer Copper Oxides"; D.C. Mattis and M.L. Glasser, "The Uses of Quantum Field Theory in Diffusion-Limited Reactions"; V.G. Storchak and N.V. Prokof'ev, "Quantum Diffusion of Muons and Muonium Atoms in Solids"; K. Bergmann, H. Theuer, and B.W. Shore, "Coherent Population Transfer among Quantum States of Atoms and Molecules"; F. Rieke and D.A. Baylor, "Single-Photon Detection by Rod Cells of the Retina"; and M. Imada, A. Fujimori, and Y. Tokura, "Metal-Insulator Transitions."

be hydrolyzed as just described. As the PtBMA derivative only contained two cross-linking groups per molecule, well-defined network films could only be obtained up to 60 mol% PtBMA monomer.

The possibility of retaining two-dimensional conformations for PMAA and PAA after hydrolysis by first cross-linking the materials means that composite structures can be assembled which differ by as little as a single monolayer. In addition to uses as models of superabsorbing polymer networks and bioadsorption studies, these materials should be ideally suited for the flexible hydrophilic spacing layers needed between supported bilayers and solid substrates for biologically relevant studies of the physical properties of membranes.

New Directors Appointed at Max-Planck-Institut für Metallforschung, Stuttgart

The Max-Planck-Institut für Metallforschung in Stuttgart, Germany has recently appointed two directors to replace the Professors Emeriti Alfred Seeger and Bruno Predel. Helmut Dosch, formerly at Wuppertal, and Eric J. Mittemeijer, from Delft, have joined the board of directors, which currently consists of Manfred Rühle (Managing Director), Fritz Aldinger, Eduard Arzt, and Helmut Kronmüller. Dosch, an experimental physicist by training and one of the international leaders in the fields of x-ray and neutron diffraction studies, phase transitions, and critical phenomena at surfaces and interfaces, plans to direct his new research division in Stuttgart into new areas of metastable and low-dimensional materials systems. The use of high brightness synchrotron radiation is particularly important in Dosch's research activities. Mittemeijer, a physical chemist and renowned expert in solid state reactions, will focus his research on phase transformations in bulk and thin-film materials. The relation between the thermodynamics and the kinetics involved and the role of structural imperfections, including the (residual) stresses, are topics of main interest. Both new directors will jointly be affiliated with the University of Stuttgart where they hold full professorships in physics and physical metallurgy, respectively.

MEMS "Trampolines" Measure Magnetization of Materials in Large Magnetic Fields

Researchers have built microscopic "trampolines" to help measure a material's magnetic properties when placed in a strong magnetic field. These devices fall

in the class known as micro-electro-mechanical systems (MEMS), which are used in various industrial applications. The top part, or "net," of the silicon-based trampoline is $300 \mu\text{m}^2$. Each of the net's four corners is supported by a spring that is $2 \mu\text{m}$ wide and $100 \mu\text{m}$ long. The technique, reported in the May 1 issue of *Science*, will provide researchers with a powerful method to study new materials for wireless devices, integrated circuits, and many other applications.

In the experiment, the researchers glued a microscopic chunk of a superconducting sample, BEDT [bis(ethylene-

dithio)], onto the trampoline. Although the technique would work with a wide range of superconducting and non-superconducting materials, the researchers selected BEDT because its properties were well-known. In addition, superconductors are inherently important materials because they lose all electrical resistance at low temperatures. Potential applications for superconductors include transmitting power more efficiently over superconducting power lines and building very high-speed electronic circuits.

Physicist David Bishop at Bell Labs and his colleagues exposed the BEDT to a

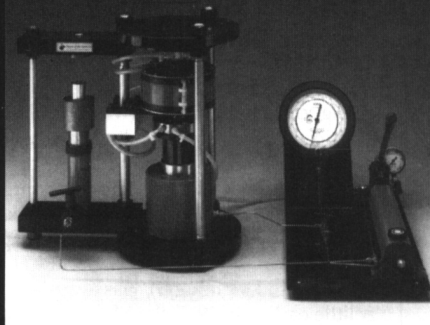
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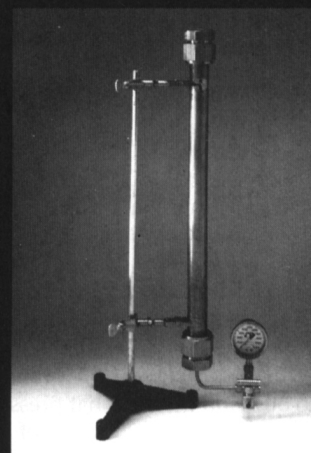
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magnetic field, the force of which caused the BEDT to move as it became magnetized. As the trampoline's net bobbed up and down, the researchers were able to determine BEDT's magnetic properties, which are an important clue for researchers when studying why only certain materials exhibit superconducting qualities.

Physicist Vladimir Aksyuk said, "This is the first time that a MEMS device has been used to measure the magnetization of such a small amount of material in a high-strength magnetic field in an extremely short time period."

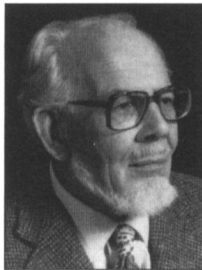
Until the MEMS trampolines were developed, researchers were unable to accurately measure the magnetization of important materials in very large magnetic fields. Other techniques either were too insensitive or failed as the environment became increasingly hostile.

NAS Chooses 60 New Members

The National Academy of Sciences announced in April the election of 60 new members and 15 non-U.S. associates from 10 countries in recognition of their distinguished and continuing achievements in original research. Election to membership in the Academy is considered one of the highest honors that can be accorded a U.S. scientist or engineer. The total number of current active members is now 1,798. Non-U.S. associates are nonvoting members of the Academy, with citizenship outside the United States. The total number of associates is now 310. Among the newly elected members and their affiliations are Materials Research Society members **David E. Aspnes**, professor, Department of Physics, North Carolina State University—Raleigh; **A. Welford Castleman**, Evan Pugh Professor, Department of Chemistry, The Pennsylvania State University; and **Miles V. Klein**, professor of physics and director of the Science and Technology Center for Superconductivity, University of Illinois at Urbana-Champaign. For a full list of NAS members and associates, see website <http://www.nas.edu/>.

Solid Hydrogen at 342 GPa, 300 K is Nonmetallic

Research at Cornell University calls into question theories that pressures close to that found at the center of the Earth would turn hydrogen into a metal. As reported in the May 7 issue of *Nature*, "Calculations suggest that depairing (destruction of the molecular bond) should occur around 340 GPa, accompanied by the formation of an alkali metal at



Frederick Charles Frank, born on March 6, 1911, died in Bristol, England on April 5, 1998. He had spent 52 years of his long life attached to the famous Physics Department of the University in that city. He was one of the founding fathers of materials physics, though his ultrabroad interests were not restricted to materials. Born in South Africa to English parents, he left that country a few weeks afterwards. After studies in Oxford, he spent two years as a postdoctorate in Berlin. During his time in Berlin, Frank learned physics from a renowned nucleation expert, Max Volmer, that helped him formulate his crystal growth theory. Early in the Second World War he made major contributions to Intelligence, especially to the interpretation of aerial photographs.

After the War, in 1946, he joined the Bristol Physics Department, and began what was arguably his most remarkable research, the prediction of the crucial role of screw dislocations in facilitating the growth of crystals. In collaboration with W.K. Burton (an industrial crystal growth specialist) and N. Cabrera, he worked out the theoretical supersaturation which would be needed for the *ab initio* creation of a new plane of atoms on a crystal and found that the observed supersaturation was much smaller; growth on the fringes of a screw dislocation rendered creation of a new plane unnecessary. Soon after came experimental confirmation of his prediction, under dramatic circumstances. Spiral growth of crystals was soon reported from all over the world—a fine illustration of how theory can open experimentalists' eyes.

As a sideline merely, he built upon some observations of his nuclear physicist colleague, Cecil Powell, and predicted the phenomenon of muon-catalyzed fusion in a precocious paper in *Nature* in 1947. He moved on to major innovations in dislocation theory; for example, jointly with Thornton Read of Bell Labs, he predicted the "Frank-Read dislocation source" in crystals. Later, under the stimulus of a Hungarian colleague, Andrew Keller, he became fascinated by polymer crystals; he played a major part in the discovery, around 1960, of folded-chain polymer crystals, and gave rather better than he got in the protracted and acrimonious disputes with adversaries such as Paul Flory as to the mode of genesis of such crystals. A splendid account of the whole story was published by Keller in a book of essays to mark Frank's 80th birthday (*Sir Charles Frank*, edited by R.G. Chambers et al., Adam Hilger, London, 1991); this book provides a superb impression of Frank's scientific personality and achievements.

Frank moved on to active interest in the behavior of flowing polymer melts and the strength of aligned polymer chains (which, like all his other researches, had a major effect on industrial practice), in the nature of disclinations in liquid crystals, and latterly he even contributed to geophysical issues such as the formation of natural diamond and aspects of plate tectonics. His influence on materials physics and on the outlook of his numerous collaborators was intense. He could always help a flummoxed student by drawing on his uniquely capacious scientific memory, which was allied to exemplary patience.

He was elected to the Royal Society at a young age and, among many other honors (including a British knighthood), was awarded the Society's Copley Medal, its highest honor, in 1994. A little earlier, in 1987, the Materials Research Society had awarded him its highest honor, the Von Hippel Award for "his wide ranging impact on modern materials science through seminal contributions in areas of inorganic crystals, metals, polymers, and liquid crystals; and his outstanding research in crystallography, chemistry, physics, and materials science which exemplifies the interdisciplinary approach." Upon acceptance of the award, he lectured on a delightfully obscure aspect of preferred orientation in polycrystals.

One can echo Shakespeare and say that, take him for all in all, we shall not see his like again.

ROBERT W. CAHN

Charles L. Hamermesh, technical director of the Society for the Advancement of Material and Process Engineering (SAMPE) and editor of *SAMPE Journal*, passed away on March 25 in Southern California. He had recently been selected as a SAMPE Fellow as a result of his outstanding contributions to SAMPE and the material and processing industry over the last 39 years. He held 15 patents on foam technology and processing, including three licenses, and has written numerous technical publications in the polymers and composites processing field. He is best known for conducting technical seminars, clinics, and short courses on polymer chemistry, composite materials, low observable materials, and materials processing during the past 20 years.

Hamermesh previously had been the group leader and manager of Polymer Synthesis and Processing at the North American/Rockwell International organization from 1959 to 1985. He also served as a consultant to the industry since 1985.

In his recent capacity as SAMPE's technical director, he served as the program director of the joint SAMPE and Department of Transportation/State of California (Caltrans) Program on the use of fiber-reinforced plastics for Seismic Retrofit and Rehabilitation (SRR) of structures. The SRR Program, under his direction, has been evaluating the use of composite materials and processing for improving structures durability and seismic resistance within the community. Several bridge column retrofits and bridge structure applications have been implemented to date as a result of this program.

this pressure or at substantially higher pressures." But the researchers found that solid hydrogen showed no signs of looking like a metal at pressures of up to 342 GPa at 300 K.

These pressures were achieved by compressing the hydrogen in a diamond anvil cell with a 20- μm -diameter tip. The researchers used a tungsten gasket. Energy disperses x-ray diffraction measurement of the tungsten gasket adjacent to the hydrogen sample allowed determi-

nation of the sample pressure. The researchers brought the sample from 0.204 GPa to ~50 GPa in less than 1 min, then to 270 GPa in less than 30 min, decreasing the possibility of hydrogen attack on the diamond. Some of the diamonds, however, despite their seeming perfection, ultimately cracked. In all, the team cracked 15 pairs of diamonds. Arthur Ruoff, the Class of 1912 Professor of Engineering and Materials Science at Cornell, speculates that the hydrogen next to the diamond surface diffuses along dislocations and into the diamonds, causing cracking. Ruoff and his colleagues previously have used the diamond anvil cell to make metallic oxygen, sulfur, and xenon. Recently researchers at Carnegie Institute in Washington, D.C. reproduced these experiments on metallic sulfur, but at low temperatures, and found that the material becomes a superconductor at 10 K when the metallization pressure is reached. The failure of solid hydrogen to become an alkali metal even at extreme pressures, according to the article, "has implications for our current theoretical understanding of the solid-state phase."



German Receives 1998 PSES Premier Research Award

Randall M. German, Brush Chair Professor in Materials with the Engineering Science and Mechanics Department at The Pennsylvania State University, is recipient of the Penn State Engineering Society (PSES) Premier Research Award. This award recognizes and rewards an individual whose contributions to scientific knowledge through recent research are exemplary and internationally acclaimed. German's research and teaching focus is on particulate materials processing. He is author of eight books on powder metallurgy and sintering, he heads the P/M Lab at Penn State, and he is a member of the Materials Research Society.

Singh Receives Electrochemical Society Award

Rajendra Singh, D. Houser Banks Professor of Electrical and Computer Engineering at Clemson University, has

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received the Thomas D. Callinan Award from the Dielectric Science and Technology division of the Electrochemical Society in recognition of his outstanding technical contributions in the development of new materials and processes for future generations of microcomputers and microcircuits. Singh, who is director of the Clemson-based Center for Semiconductor Device Reliability Research and the Materials Science and Engineering Program, has published more than 200 technical papers and is a Fellow of the Society of Optical Engineering and the American Association for the Advancement of Science.

Katz from CWRU Receives Career Achievement Award from IEEE

J. Lawrence Katz, Professor of Biomedical Engineering at Case Western Reserve University, has received the Career Achievement Award from the Engineering in Medicine and Biology Society of the Institute of Electrical and Electronic Engineers for contributions to ultrasonic wave propagation studies and bone properties and introducing the analysis of those properties based on a hierarchical composite material model. Katz has two patents and over 150 publications dealing with biomaterials and biomechanics for bone and teeth. He is a Fellow of

IEEE, The American Society of Mechanical Engineers, The American Physical Society, an Inaugural Fellow of the Society for Biomaterials, and a member of the Materials Research Society.

HTS Energy Loss Due to Cracks Formed During Manufacturing and Grain Boundaries

High-temperature superconducting materials formed into wires or tapes can lose as much as 95% of the current running through them. Researchers at the University of Wisconsin—Madison have found tiny defects that clog electrical flow through the wires. As reported in the April 30 issue of *Nature*, David Larbalestier, director of the university's Applied Superconductivity Center (ASC), said that while some current is blocked by grain boundaries made when the material is crystallized, most energy is lost from synthetic defects introduced by the manufacturing process.

The research team tested a 2-mm-thick superconducting BSCCO (Bi_yPb)₂Sr₂Ca₂Cu₃O_x tape filled with 85 filaments, 5–10 μm thick. ASC scientist Cai Xue-Yu tested individual filaments extracted from these tapes and, through magneto-optic imaging, revealed cracks that were characteristic of the cracks produced by the intermediate rolling step required to densify the

tape after its first heat treatment. Such cracks, the article reports, "interfere with longitudinal current flow over large areas." Larbalestier said that cracks are difficult to eliminate completely from manufacturing, but this research points directly to the need for fabrication techniques to reduce the problem.

Easily Desolved Molecular Boxes Produced

Researchers at the University of Illinois at Urbana-Champaign have built a molecular box for future applications of host-

SBIR Update

Superconductive Components, Inc. (Columbus, Ohio) has been awarded a \$70,000 SBIR grant by the National Aeronautic and Space Administration to work with Oak Ridge National Laboratory to develop a superconductive toroid that potentially shields gravity waves.

MicroCoating Technologies (MCT) (Chamblee, Georgia) has received a Phase II Small Business Innovative Research (SBIR) grant from the Department of Energy to continue work toward improving superconductor results to a targeted T_c of 90 K and J_c of 1 million A/cm².

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guest chemistry. The box is $\sim 5 \text{ \AA}$ on a side with an internal volume of $\sim 132 \text{ \AA}^3$. The molecular boxes are symmetrical with alternating corners of cobalt and rhodium atoms, bridged by 12 carbon-nitrogen ligands. The octahedral binding nature of the metal atoms provides the necessary three-dimensional geometry to assemble the boxes. Thomas Rauchfuss, professor of chemistry and a researcher at the university's Beckman Institute for Advanced Science and Technology, said, "The box-like cores of the resulting molecular cages resemble subunits of the Prussian blue lattice, which is a very stable dye. But, unlike Prussian blue and similar zeolites and molecular sieves—which are insoluble—the new molecular boxes are easily dissolved."

As reported at the American Chemical Society national meeting in Dallas March 29–April 2, Rauchfuss, visiting postdoctoral research associate Kevin Klausmeyer, and research chemist Scott Wilson began with pre-organized building blocks with four cobalt "corners" that each come with three built-in edges. The researchers added the rhodium atoms as four additional corners to form the box. They then replaced some of the carbon nitrogen ligands with cyclopentadienyl (Cp) groups that block the faces of the metal octahedron and prevent further growth. The Cp groups not only prevent the individual boxes from fitting together into chains, they also force the polymerization to grow toward the middle of the box.

Rauchfuss said, "The Cp groups are crucial because they allow us to assemble a molecule instead of a polymer. But they are also interesting because there is so much organic chemistry we can do with them. Down the road, we want to make boxes that are negatively or positively charged in order to modify the host-guest chemistry."

Aerogel Tile Composite Serves as Insulator

Tiles with a layer of aerogel mixed into the tile's air spaces, a concept designed for spacecraft tiles, also serve as insulation for refrigerators, furnaces, and automobile catalytic converters. "The aerogel used to fill the air spaces inside the tiles is like strings of nanosized pearls, all tangled up," said aerogel tile co-inventor Susan White of Ames Research Center of the National Aeronautic and Space Administration (NASA).

The fibers that form the tiles are mostly a mixture of silica and alumina oxides, according to co-inventor Daniel Rasky, also of Ames.

White said, "The reason the aerogel tile composite will act as a great insulator for keeping freezers cold, or automobile catalytic converters hot, is that the air flowing through the tile is almost completely blocked by aerogel. It is like having a chunk of solid vacuum where you need it. Aerogel is very brittle and can't be machined, but spacecraft insulation tiles filled with a layer of aerogel can be cut, machined, drilled and attached to a surface."

The aerogel tiles could also be used to insulate future spacecraft from the heat of reentry into the atmosphere. According to White, the aerogel tiles will protect future spacecraft from very high reentry temperatures and from ice formed on the fuel tanks when the vehicle is waiting on the pad for launch.

High temperature and environmental testing of aerogel space tiles was conducted at Ames for seven years. A patent is pending for the new material. □

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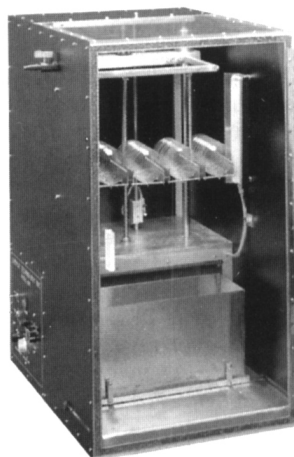
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