The National Bureau of Standards Prepares for the 1970's

Astin, who brought about the move to the ultramodern Gaithersburg facility, hands over reins to Branscomb.

After 17 rewarding years as director of the National Bureau of Standards (NBS), Allen V. Astin retires this week. Probably no other scientist-administrator can look back upon a career so long and distinguished that began in near-disaster. Before Astin had completed his first year in the top NBS post, he was ousted and then reinstated, as a result of the white-hot controversy over the role and the competence of NBS in testing commercial products, the case in point being a battery additive. What emerged was a test, not of additives, but of NBS and its new director, with far-reaching and long-term consequences for government science. Astin and his Bureau emerged stronger than ever.

Lewis M. Branscomb, the Bureau's new director and the former chief of the NBS Laboratory Astrophysics Division at Boulder, Colorado, recaptured the mood and reviewed the significance of the crisis in a talk last year to a group of physicists in Chicago:

> In 1953 the AD-X2 battery-additive affair saw the director of the National Bureau of Standards fired for the failure of NBS to include the "play of the marketplace" in testing procedures for automobile batteries. We learned that opposition also could be heard from some elements of the business community: Beware of letting science come between the manufacturer and his customers.
>
> Considering those difficult and rather recent days, the subsequent degree of accommodation between science and both business and government has been quite remarkable. Technology is now acknowledged to be the driving force for increases in productivity in our new economy. I need not describe the panoply of mechanisms for inflicting scientific advice on the executive branch of the government.

The improved climate described by Branscomb was in large part a result of Astin's systematic efforts in the aftermath of his AD-X2 ordeal. One of the crucial complications that had blown up the affair to major proportions, Astin reflected, was the existence of other laboratory findings ostensibly at odds with those of NBS, suggesting an unfortunate lack of compatibility in methods and measurements. The crisis further fueled his abiding passion to build a system that would afford comprehensive compatibility of measurement throughout the United States. Not only would he preserve the Bureau's integrity, he would strengthen its competence to do the required work, and would win the nation's complete confidence in NBS findings. Compatibility, competence, and public confidence were to be watchwords of his administration.

In his pursuit of competence the director was confronted with numerous problems in addition to the ever-present one of attracting and holding a staff of excellent scientists. They included inadequate facilities; old buildings; outmoded laboratories; cramped, overcrowded quarters; and environmental interference with delicate laboratory measurements as metropolitan Washington encroached upon the Bureau's once uncrowded location in northwest Washington.

Fortunately a postwar policy of strategic decentralization could be turned to advantage in seeking a new location and new facilities. By 1955, therefore, Astin began planning for what has since grown into his monumental physical legacy to NBS—the complex of ultramodern laboratories on the 570-acre site near Gaithersburg, Maryland, which today constitutes NBS headquarters. The "big move" began with the purchase of the Gaithersburg-area farmland in 1956 and only recently neared final completion as the Fluid Mechanics Laboratory —the 20th and last of the primary structures called for under the original blueprint—was opened in a turnkey ceremony.

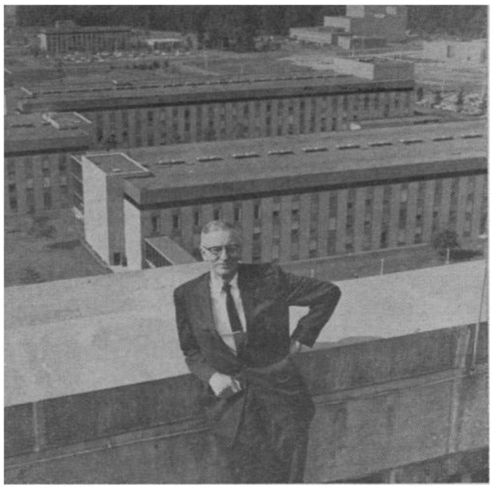
In moving 20 miles to the northwest into the new "scientific corridor" growing up outside of Washington, the Bureau has provided its scientists with laboratories equipped to take advantage of the latest advances in precision measurement.

The spacious site reduces environmental interference within NBS and with exterior neighbors. The modular construction of the general-purpose laboratories provides flexibility and multiplicity of essential services for the changing needs of research.

Special-purpose laboratories house unique facilities requiring special structures. Some are truly one-of-a-kind, with capabilities sufficient to justify their being considered national resources to be shared—as they are—with other government agencies and with private institutions. Among these facilities are a 100-Mev linear electron accelerator with a beam of up to 65 kilowatts (page 870); a 10-megawatt high-flux reactor with a unique cold-neutron facility (page 871); a 1-million-pound deadweight machine and an associated 12-million-pound hydraulic testing machine (page 870); and an Environmental Engineering Laboratory, incorporating a full-size "house" which is subjected to artificially created climatic conditions for studing heat losses through walls, roofs, and foundations, and for other such purposes.

In providing these splendid new facilities for NBS, Congress has reaffirmed the nation's support of an institution devoted to meeting the basic need for compatibility of measurement throughout the dynamic, technologically based U.S. economy. At the same time, Congress's action expresses the government's confidence in the existing institution, with its 68 years' experience, and challenges it to develop and utilize the full potential of the new facilities. This, if accomplished, will provide technological support and economic benefits far exceeding the initial investment.

During the years of Astin's stewardship the need for basic research in a science-based, mission-oriented government laboratory has become better understood. If NBS is to provide the central basis of the nation's measurement system and ensure the requisite compatibility of measurement for all sectors, leadership is essential—a leadership based upon competence, integrity, and confidence, not upon statute. Since measurement advances occur at, or spark scientific advances at, the frontiers, recognized scientific competence is crucial. In the early postwar years, emphasis was placed on strengthening basic-science capability—on developing a staff



Allen V. Astin atop the central Administration Tower of the new laboratory complex for NBS at Gaithersburg, Maryland. Some of the general purpose labs (foreground) and special purpose labs (background) are shown in this panorama of the 570-acre countryside site.

of high competence and orienting it to meet the nation's demand for measurement capability. Accompanying this push for competence and attesting to its realization was a stream of notable contributions to basic science. These included demonstration of the nonconservation of parity in weak field interactions in 1956; isolation of free radicals and study of their properties (page 874)—research which was accompanied by the widespread use of cryogenic techniques for many new laboratory purposes; explanation of properties of polymer crystals by means of chain-folded molecules (page 872); and, more recently, a contribution to the study of the failure of time reversal.

This competence brought to NBS an infusion of new ideas, concepts, techniques, and instrumentation. These provided the base for more scientific contributions of the type required to strengthen and refine the basic tie points for a compatible measurement system and to extend the system to new regions in the realm of measurement.

Fundamental constants of physics which couple the measurement system reproducibly with nature were determined with unparalleled accuracy. The gyromagnetic ratio of the proton was carefully measured; as a by-product, this provided the basis for accurate measurement of magnetic fields throughout the world. Determinations of the velocity of light by means of lasers (page 873) more accurate than earlier instruments by two or three orders of magnitude are now in progress. The success of such projects is essential for extended adventures in space. One of these has already happened with the placement of a cooperatively built lunar reflector on the moon during the epochal visit of Apollo 11 (page 873). Reflections of laser pulses sent from earth promise more accurate lunar distances and also open new possibilities for the measurement of continental drifts on earth.

In the realm of standards for physical meaurement, old standards such as those for length and time were defined in terms of atomic properties; thereby the standards were made independently reproducible, and their accuracy was extended by several orders of magnitude. The cesium frequency standard (page 871) and the krypton length standard (page 874) are two outstanding examples. Force standards were developed to meet the needs of the great rockets for the space thrust.

New means for making absolute-temperature measurements that extend the thermodynamic temperature scale to cryogenic temperatures have led to development of an acoustic thermometer based upon the velocity of sound in helium gas (page 873) and give promise of yielding a thermometer for making measurements at approximately 0.005 degree Kelvin, based upon thermal fluctuations of voltage in a recently developed superconductor Josephson junction (page 873). Similarly, Josephson junctions used in a different technique promise to yield an improved standard of voltage (page 873).

The whole philosophy of calibration, the means by which the measurement system is locked to the central standards, is undergoing revision. In the new approach the user is sent an object to measure; thus his whole measurement procedure is calibrated, instead of his instrument only, if he sends it to NBS. Standard reference materials, which are used in analytical processes and in the measurement of material properties, have been issued in hundreds of new forms, reaching now into the much-needed area of medical-biological measurements (page 874).

Lewis M. Branscomb, appointed to succeed Astin as director, National Bureau of Standards.

The Bureau's traditional role in those parts of the measurement system that deal with the physical properties of matter and materials has come in for similar revision. Careful measurement of properties is wasted effort unless the material under study is well enough characterized to be reproducibly available. Thus materials science, leading to the development of techniques for producing well-characterized materials, was developed to complement the steady advances in the ability to measure properties with great accuracy. Techniques such as crystal growth and high-pressure measurement with a diamond cell (page 872) yield information on properties in new environmental conditions. Industrial applications and benefits have been many. One—the discovery of a way to convert ortho- to parahydrogen during the liquefaction process (page 872)—has prevented a 50-percent loss in liquid hydrogen stored for space rockets and other uses.

To bring order out of confusion—to provide compatibility among the manifold measurements of properties in the nation's scientific, government, and industrial laboratories—the National Standard Reference Data System was launched, to arrive at and disseminate, when possible, agreed-upon best values for the measurements. This embryonic program is expected to make contributions whose economic benefits may well surpass the cost of the whole NBS operation.

In the national activity related to the measurement of man-made things—parts, devices, systems—our economy requires a meaningful basis for exchange in commerce and industry. Buyer and seller, industrial or individual, must agree upon what is wanted and make sure that it is obtained. Under Astin's leadership, emphasis on design standards (specifications) and on the measurement technology to insure that the standards are met was increased, to strengthen the nation technologically and give it a strong voice in world standardization bodies.

Closely associated with design standards are the newly emerging performance standards, which define what a device (such as a transistor) must do, or what a system (such as an electronic computer) must accomplish. A dramatic performance standard now under study is one for flammability of fabrics (page 874).

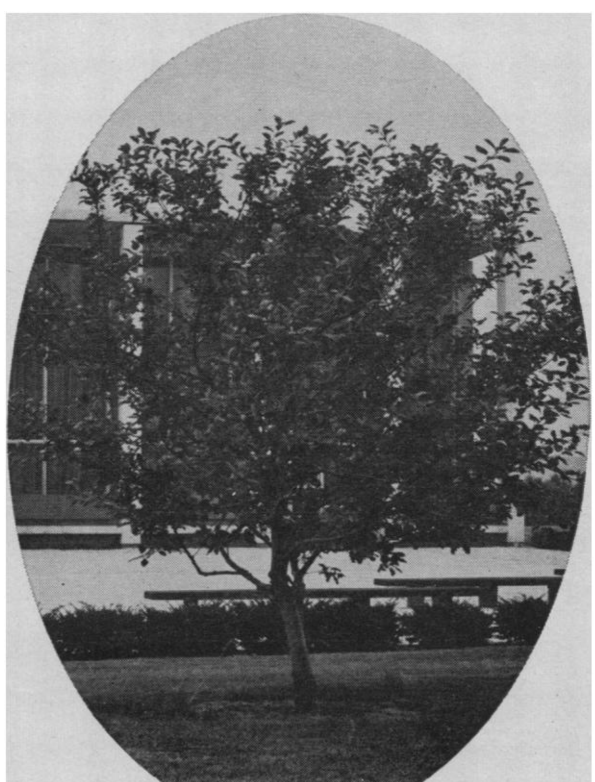
Both design standards and performance standards are based upon measurement. Design standards define what sizes of things are to be made, and measurement determines whether these specifications are in fact met. Performance standards require both an agreed-upon way of measuring, quantitatively and compatibly, the performance characteristics of a given device or system and, when this has been accomplished, agreement upon acceptable values for the measured characteristics. Thus, measurement, in a new and more complex sense, provides the foundation for all designs and performance standards. In meeting the needs of this part of the measurement system, NBS must provide the basic concepts, the measurement technology, and forums for reaching agreement in establishing the standards. Under Astin's leadership these standardization activities, already traditional in NBS, have been given increased emphasis.

The regulatory powers needed to enforce conformity with the accepted units of measure rest with the 50 states. Congress has accepted the traditional English Customary System, and has made adherence to the metric system legally permissible, and mandatory in the case of electrical units. The states have developed their own metrological laboratories, with the aid of NBS, which has provided draft legislation and physical standards of mass, length, and volume. To bring the old state standards into modern status for the next 50 years, Astin has arranged that the states are to receive new physical standards provided, they, in turn, furnish laboratories able to make full use of them (page 874). In this state-improvement program, the provision of standards is well advanced.

It is not surprising that an institution which is able to provide the basis for compatible measurement in all fields of physical science, engineering, and commerce, and which enjoys the confidence of the public and of the community of scientists and engineers, should be called upon to provide essential services in times of national emergency and to serve as a source of unbiased technical-measurement information and services. It has become a tradition to turn to NBS for analysis of failure, in aircraft disasters and of other failures that have endangered the public—such as the failure of the Silver Bridge over the Ohio River at Point Pleasant, West Virginia. In that case it was possible for NBS metallurgists to identify the chain-link fracture which initiated the catastrophe and determine the cause of the failure with sufficient certainty to warrant the closing of a similar structure.

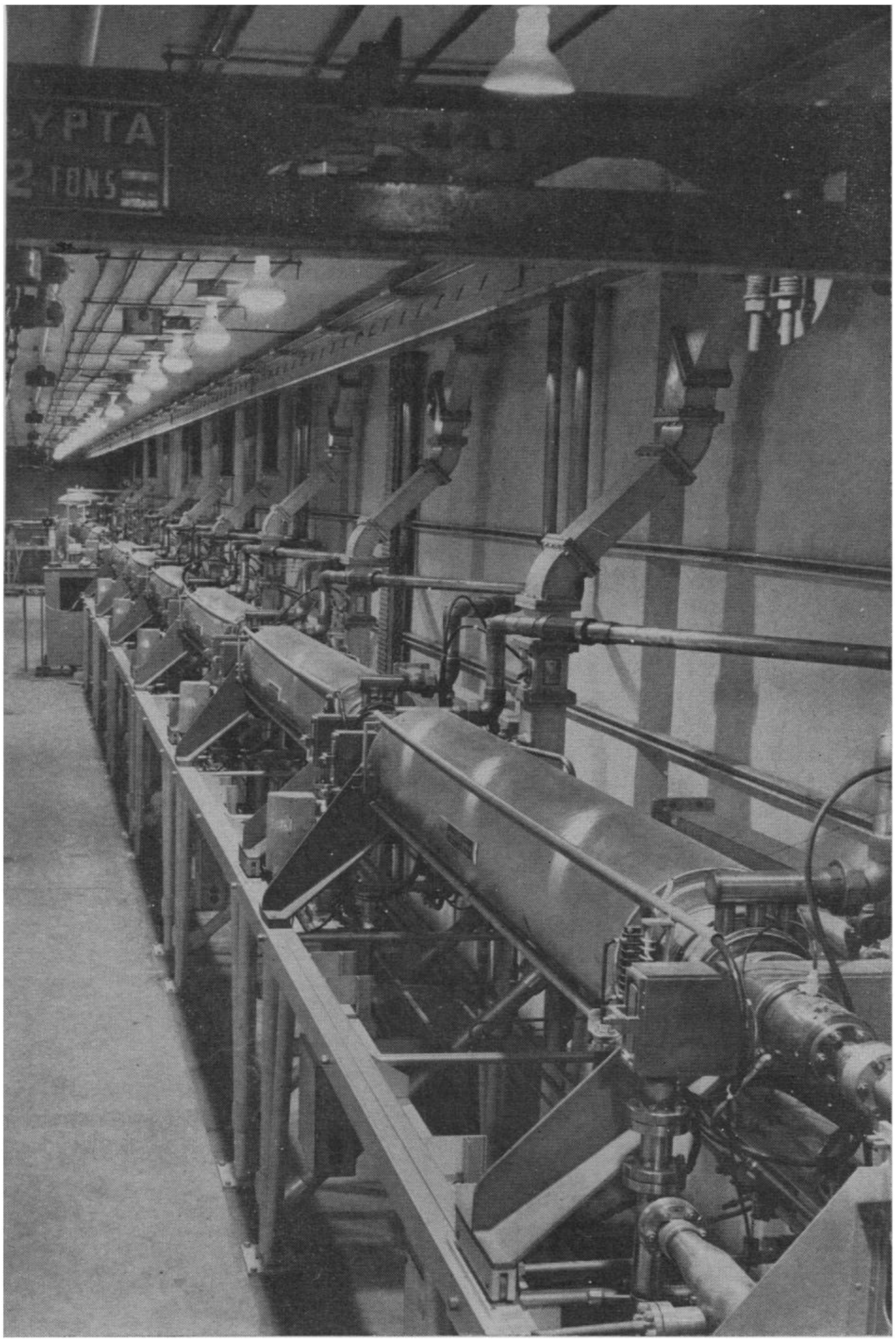
As a final act to strengthen NBS to meet the challenge of the 1970's, Astin played a key role in the nomination, as director, of a young, dynamic scientist, L. M. Branscomb, from the staff of NBS. Branscomb's career has shown him to possess the very qualities needed to lead NBS to greater accomplishments. He has pioneered the union of NBS with a university (Colorado) to bring the talents of both to bear upon the basic problems in the forefront of measurement technology.

Under the leadership of its new director NBS will move into the second year of a congressionally authorized 3-year study to help the nation make a long-needed decision about the future of its measurement system, now predominantly based on the English system in a world almost entirely committed to the metric system. Whatever the final outcome may be, the study will surely provide new insight into the nation's vital dependence upon a strong, dynamic measurement system.



Newton apple tree on the new site reminds NBS of the long tradition of coupling between science and accurate measurement. The tree grew from a cutting off the one that dropped the famous apple on Newton's head.

Material was prepared by Robert D. Huntoon, assistant to the director, NBS; Stanley Lichtenstein, Public Information Office, NBS; and Grayce A. Finger, Science.



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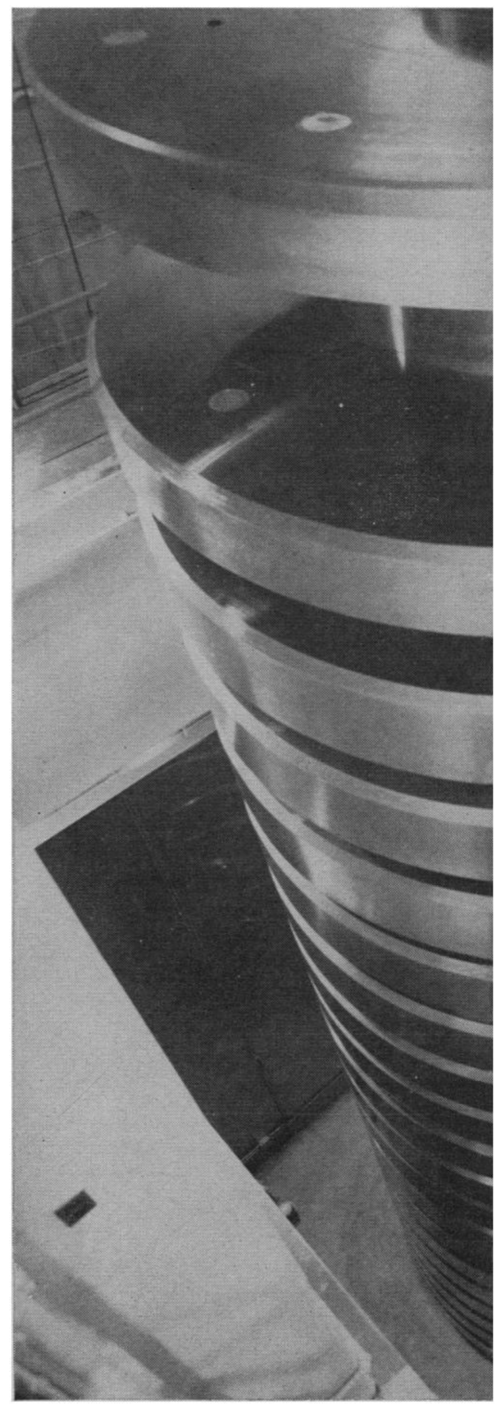
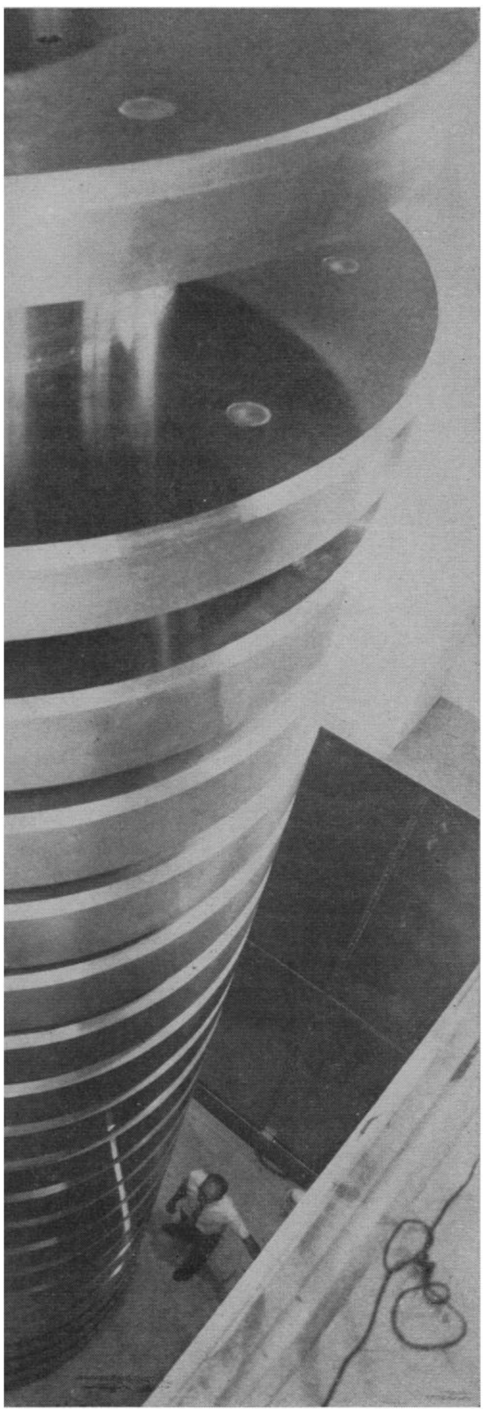


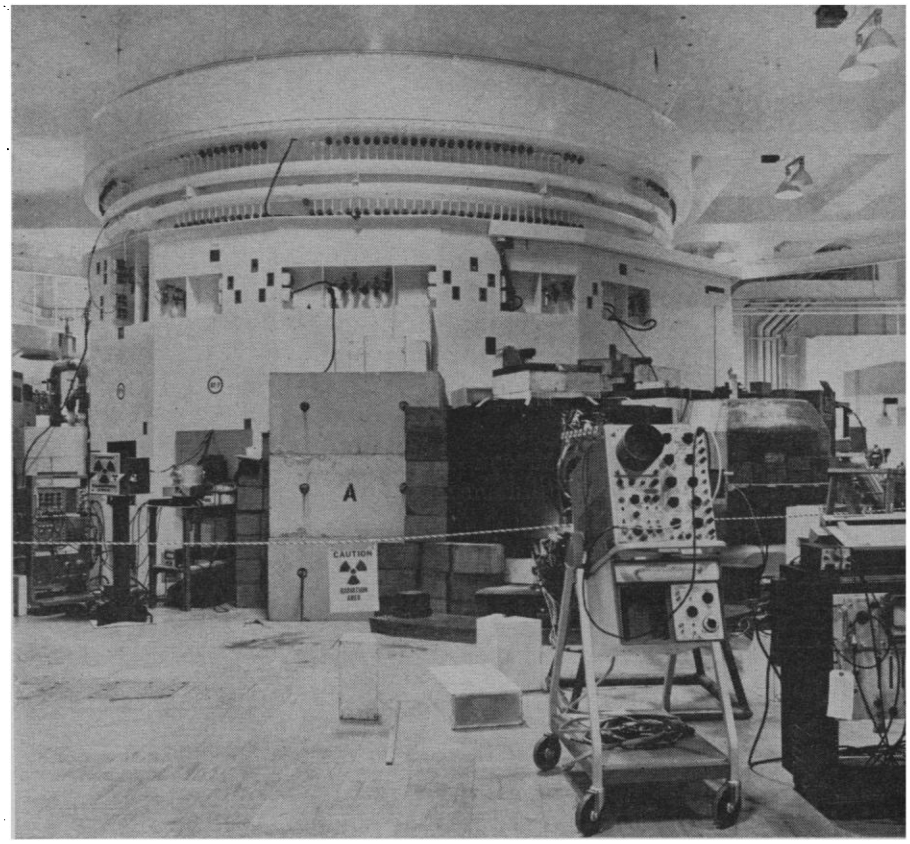
(Above) One hundred-million-volt accelerator for electrons provides world's most intense beam (65 kilowatts average power) in this high-energy region. It can provide 10 to 150 Mev electrons to three experimental rooms and eventually to an above-ground, time-of-flight neutron facility. High quality beam control provides unique capability for precision experiments.

(Right) Deadweight stack of the new 1-million-pound-force deadweight machine recently installed in the Engineering Mechanics Building. The improved calibration accuracy obtainable with this machine is of vital importance to the nation's space program. The weights, each 50,000 pounds, are 10 feet in diameter. Most of the stack is below first-floor level in a 26-foot pit. James I. Price, staff member, adjusts the temperature control.

t Work

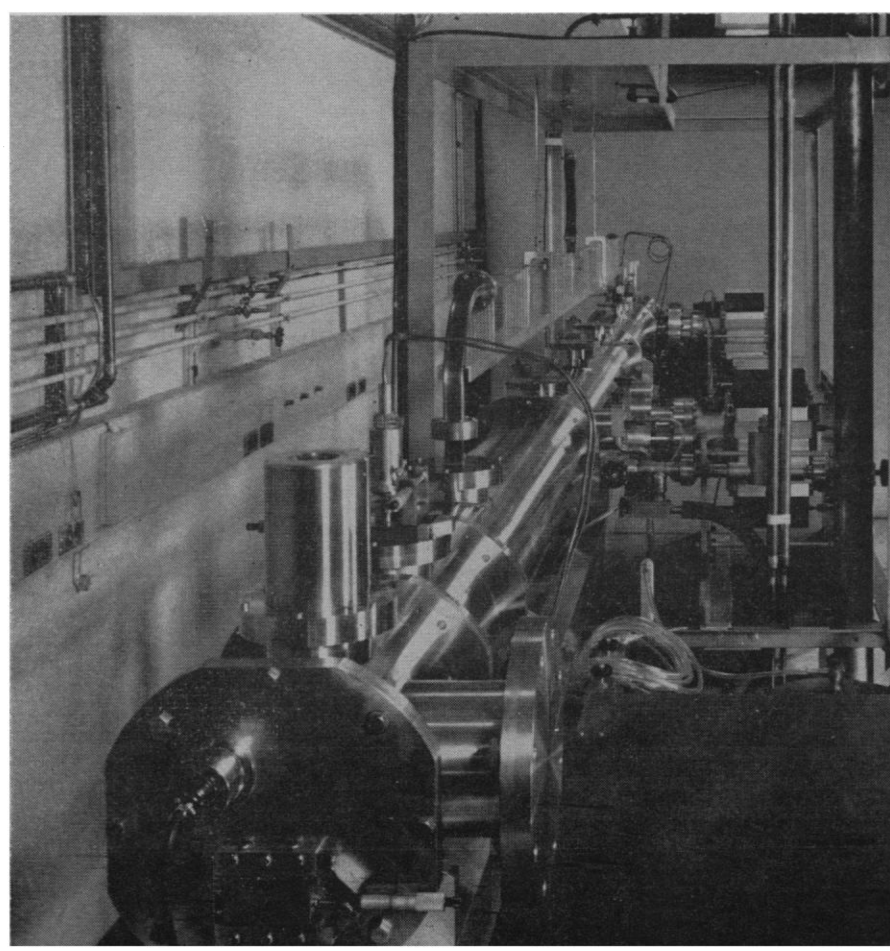
pressure cell, Josephson junction, cholesterol, and photos are from NBS]

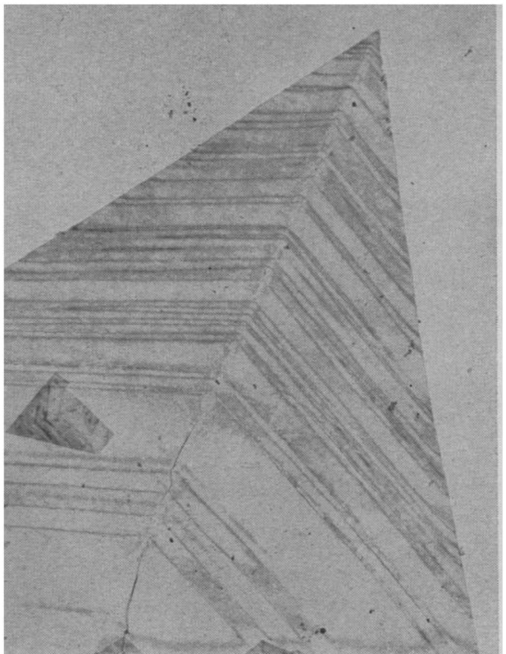


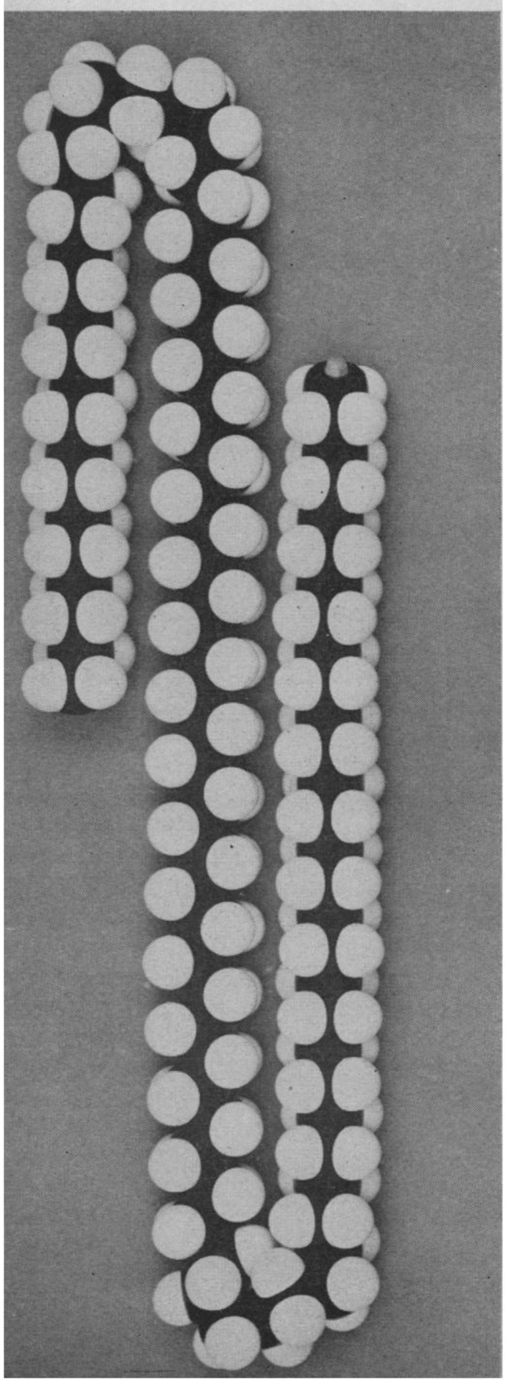


(Above) Ten-megawatt heavy water research reactor features split-fuel elements that permit beams to be taken from the central region of the reactor without directly viewing the fuel—thus avoiding high energy fission neutrons. A unique feature is a 20°K cold neutron facility with two separate beam ports. Maximum thermal neutron flux is 1.7×10^{14} (neutrons/cm^2 sec) and maximum fast neutron flux is 1.2×10^{14} (neutrons/cm^2 sec).

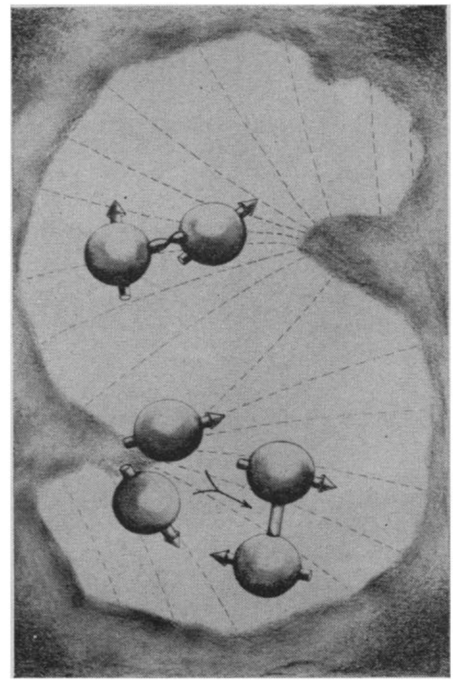
(Below) Twenty-foot cesium beam resonator which serves as present NBS Frequency Standard and provide basis for an atomic time scale, NBS-A, started in 1957. Accuracy of frequency standard $\pm$ 5 parts in 10^{12} (3σ). Improvements being incorporated this year are expected to improve accuracy tenfold.



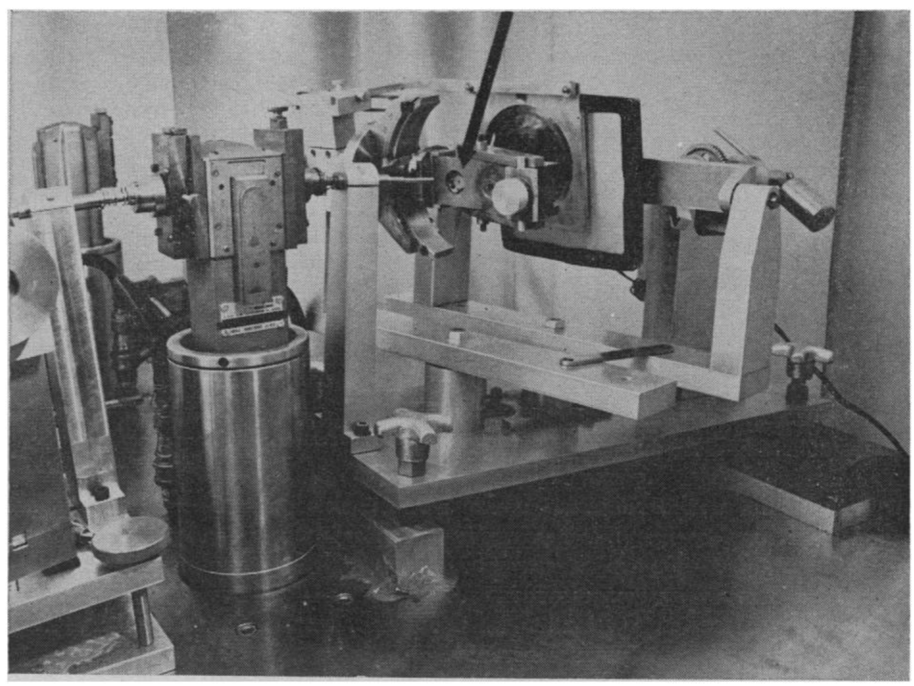




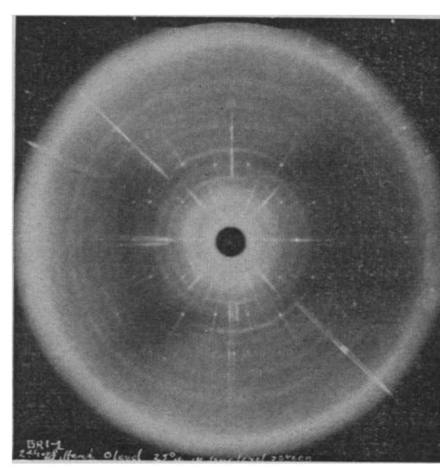
(Left) NBS basic research into polymers produced this brightfield electron micrograph of portions of lozenge-shaped lamellar crystals of polyethylene which are typically about 10 nanometers thick. The long chain, polyethylene molecules in these crystals are regularly folded in the manner depicted in the model (below) in which only two successive folds along a polymer chain are shown. The molecular stems between successive folds are oriented either at right angles, or nearly so, to the plane of these thin lozenges.



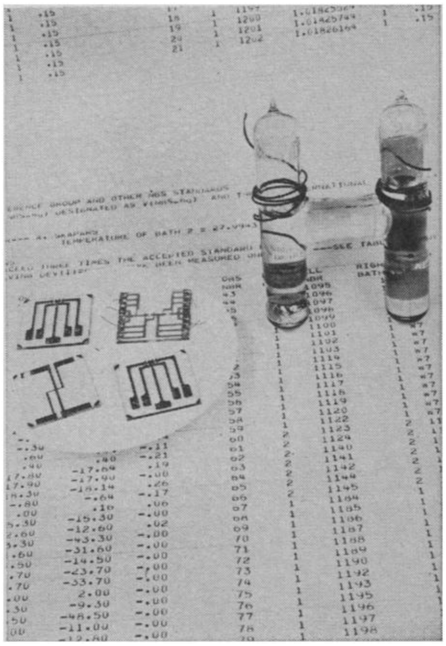
(Right) Ortho-para conversion in liquid hydrogen. Schematic representation shows ortho (top) deformed by electromagnetic field of fast catalyst discovered at NBS. It breaks its bond (lower left) and reunites (lower right) to form para. Without conversion, liquid would emerge as 75 percent ortho. Slow spontaneous conversion to para during storage would evaporate about 50 percent of liquid. Catalytic conversion during liquefaction eliminates this boil-off loss.

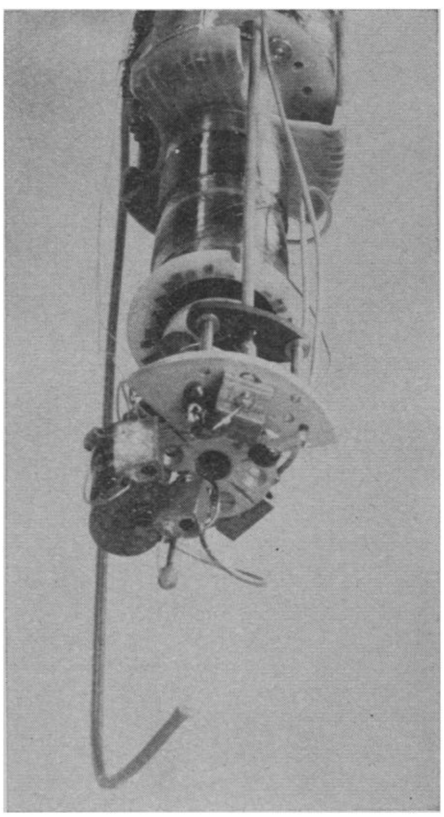


(Above) A newly developed beryllium diamond-anvil pressure cell permits x-ray diffraction data on crystals under pressures as great as 40,000 kilobars. Small enough to be held in the hand, a cell is shown mounted in an x-ray diffraction instrument (arrow). Visual and spectroscopic examinations are also possible.

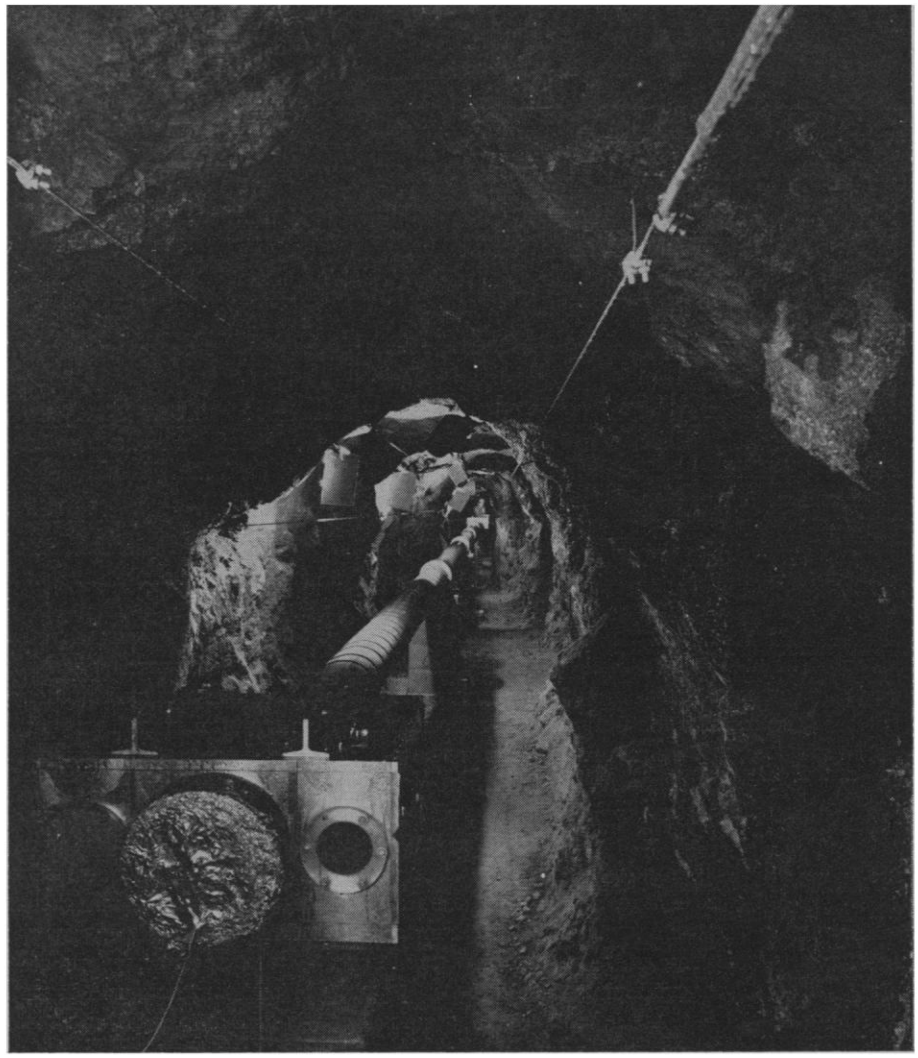


(Right) A typical x-ray pattern obtained by using the NBS beryllium diamond-anvil pressure cell—in this case showing the patterns found in a single crystal of bromine at room temperature and approximately 10 kilobars. Spots and streaks are a result of x-rays diffracted by the crystal.

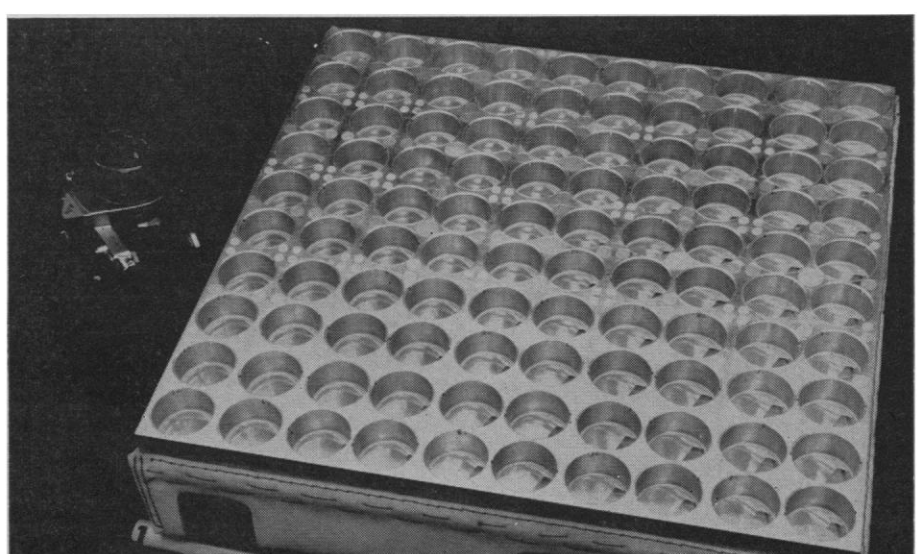


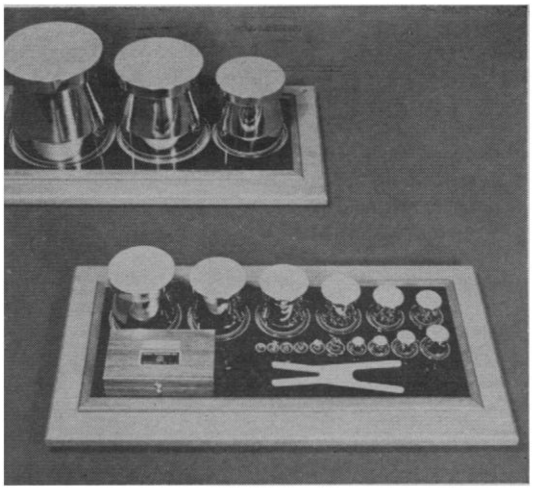


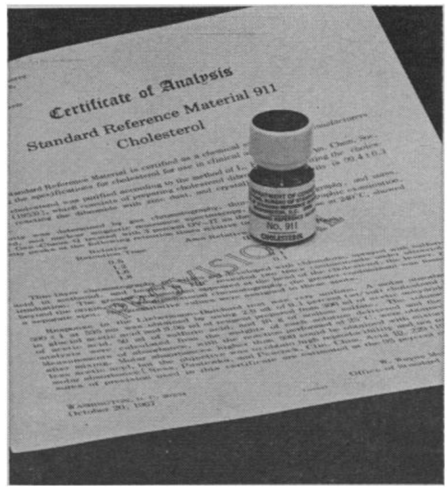
The 1962 discovery by Josephson, in Cambridge, England, of the peculiar properties of junctions between superconductors gives promise of new and improved standards for electric voltage and of very low temperature (0.1 °K). The top figure shows several junctions used for a possible voltage standard compared with a standard cell. Measurement of emitted frequencies from the junction indicates the voltage. The bottom figure shows a junction mounted on a helium dilution refrigerator. Measurement of its junction thermal voltage fluctuations indicates the absolute temperature.

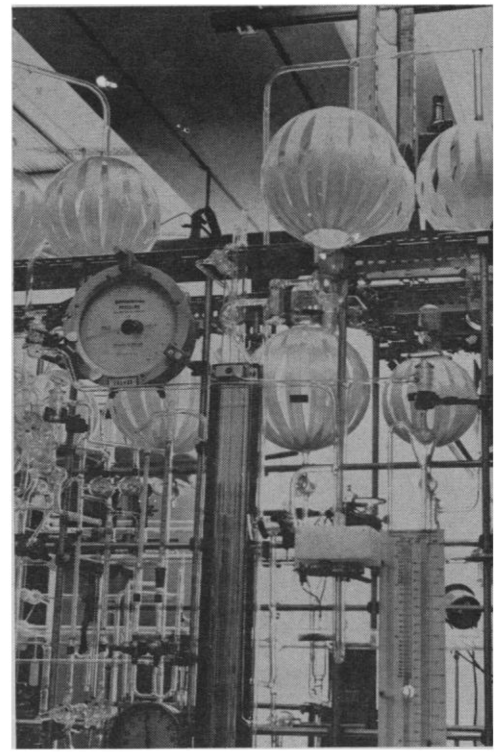


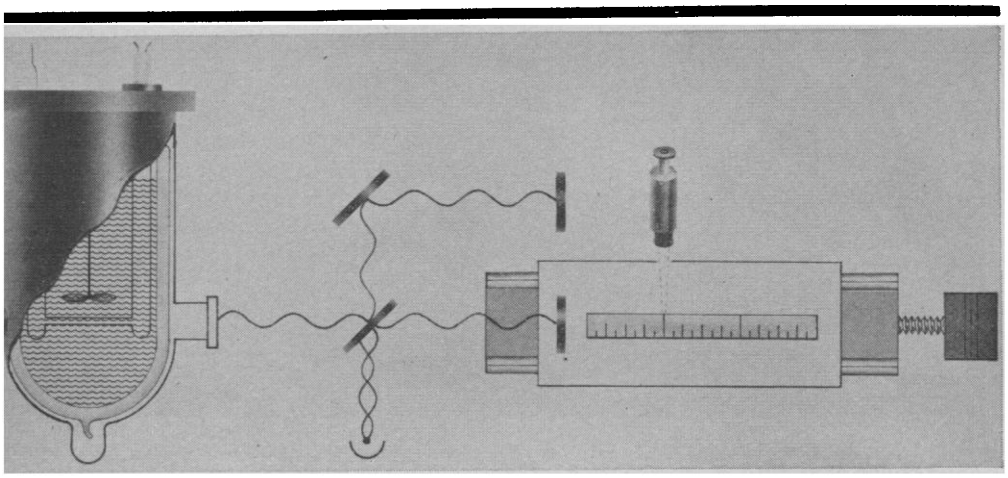
Applications of rapidly developing laser techniques include a redetermination of the velocity of light and lunar reflections. Shown above is a 30-meter vacuum interferometer installed in disused mine near Boulder, Colorado. When driven by a stabilized laser it shows earth tides and promises a new value for *c* (speed of light) with two or three orders of magnitude improvement in accuracy. Shown below is the lunar reflector developed by an interlaboratory team on which NBS was strongly represented; it was placed on the moon during the Apollo 11 visit.

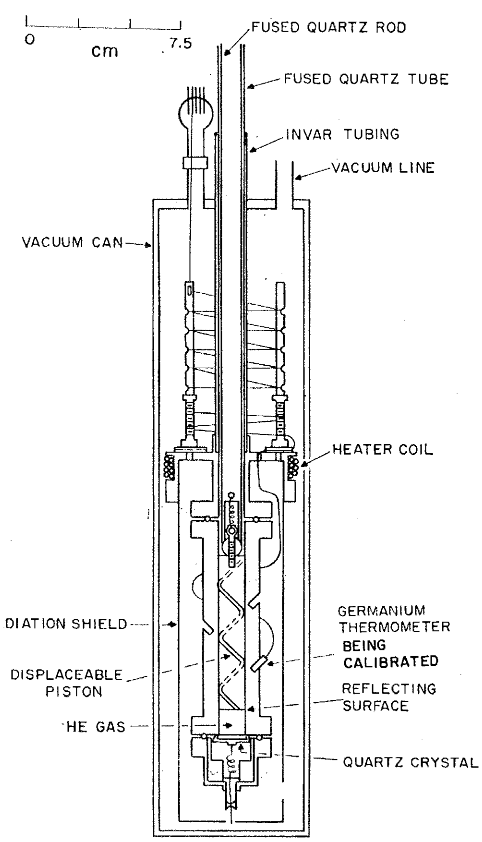








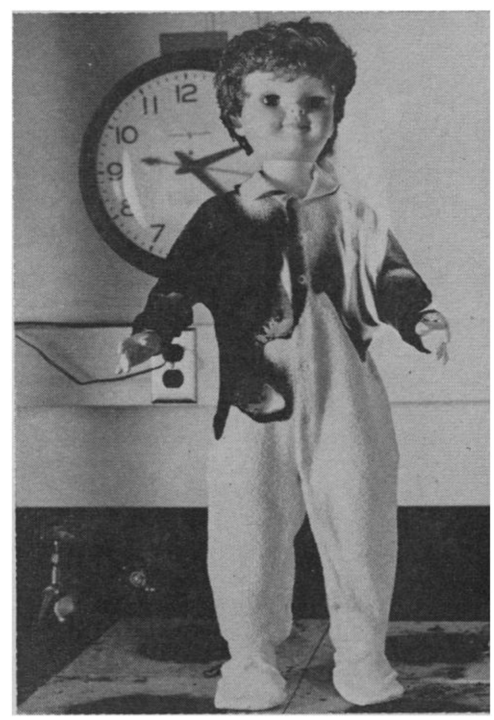




(Top, left) New State Mass Standards, 50 pounds to 10^{-6} pounds. Each state also receives metric and English standards for mass, length, and volume.

(Top, center) Standard reference sample of cholesterol, 99.4 ± 0.3 percent pure, one of hundreds of Standard Reference Materials issued by NBS for calibrating measurement systems or producing consistent data referred to a common base.

(Top, right) Chemistry of simple gaseous free radicals is studied through instrumentation utilizing flow-system techniques to produce steady-state conditions. Radicals are produced by passing a stable gas through an electric discharge, are pumped rapidly through a tube, and detected by their electron paramagnetic resonance spectrum.



(Center, right) Blazing pajamas of this mannequin, representing a young child, figure in laboratory tests on flame spread conducted by the NBS Office of Flammable Fabrics. This research illustrates NBS responsibility for mandatory standards under legislation addressed to particularly urgent situations affecting health and safety.

(Center, left) Liquid nitrogen-cooled krypton-86 light source (left) and optical interferometer (center) which counts wavelengths equivalent to a length of graduated scale (right). International agreement of 1960 specifies the meter as 1,650,763.73 wavelengths in vacuum of the krypton orange-red radiation, thus defining an independently reproducible meter in terms of an invariant atomic property.

(Lower left) Ultrasonic thermometer provides accurate thermodynamic temperature determinations in the 2° to 20°K range.