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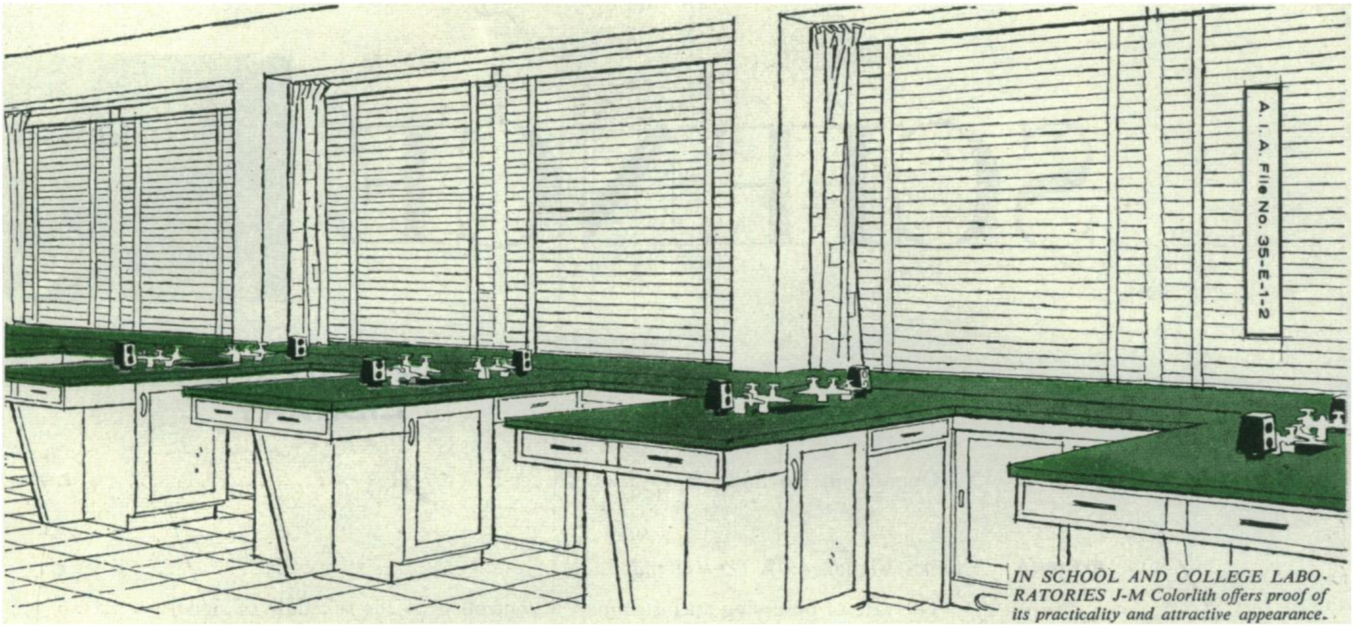

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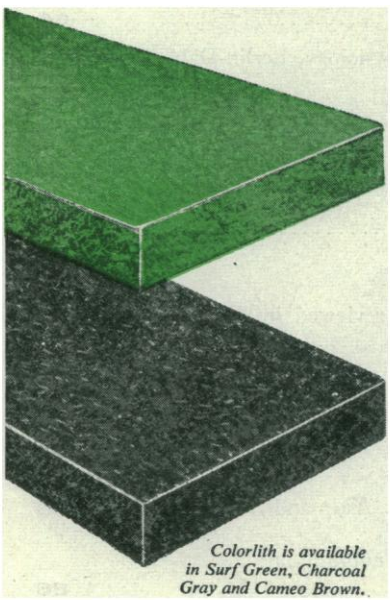

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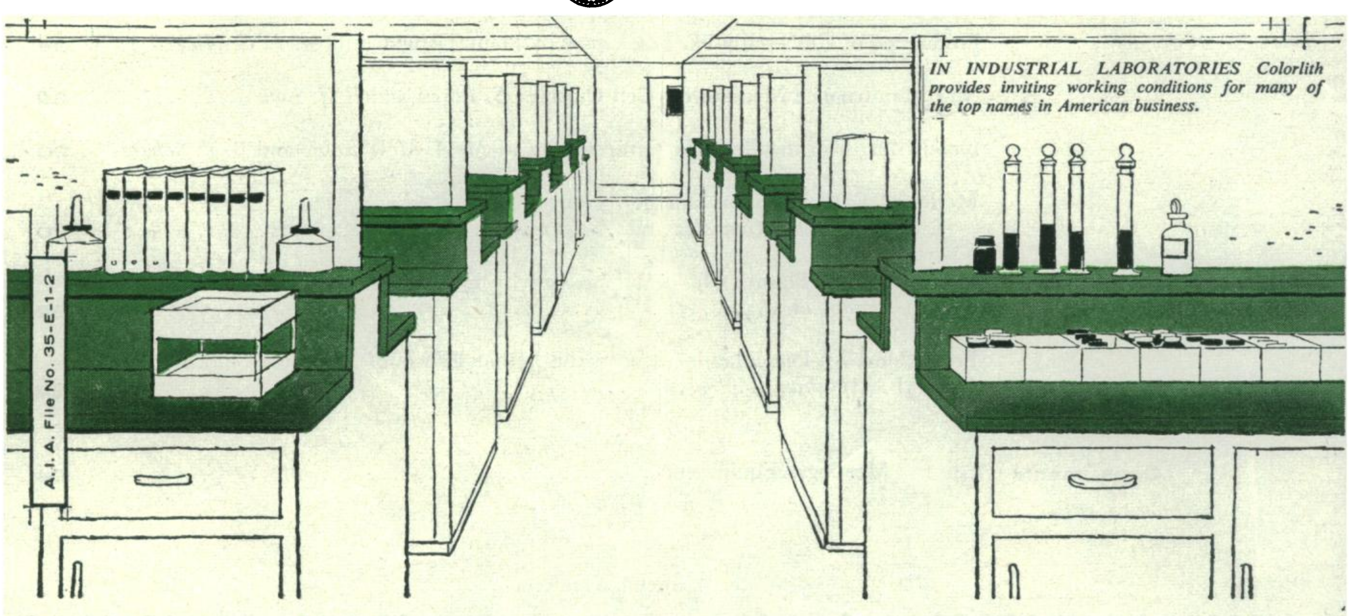

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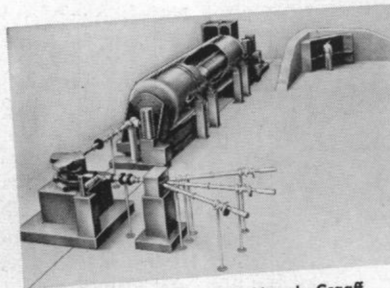
The place of the Particle Accelerator in Basic Research...

Nuclear Spectroscopy – VIII

Low-energy nuclear physics is concerned primarily with the arrangement of nuclear particles or nucleons (protons and neutrons) within the nucleus and with the nature of the forces giving rise to this nuclear structure. Studies of nuclear structure employ particles such as protons, neutrons, deuterons, and alpha particles with energies up to several million electron volts (Mev). This is in contrast to high-energy nuclear physics where particle energies of hundreds of Mev or even several billion electron volts are being used to study the interactions of the elementary particles themselves.

Although the structure of the nucleus has been the subject of extensive research for many years, we are still without a comprehensive theory of the nucleus. Much experimental and theoretical work remains to be done in the field of low-energy nuclear physics before we will have a theory as complete as that in atomic physics which describes the extra-nuclear electronic structure of the atom.



Model of new Tandem Van de Graaff

Studies of Nuclear Structure

Similar to this electronic structure, the nucleus is found also to have a structure consisting of discrete energy states in which the nucleons can exist. Determinations of energy levels, level spacings, and particle binding energies are the essential problems of nuclear spectroscopy. Just as the mass of experimental data on atomic spectra was synthesized by the Quantum Theory developed in the 1920's, so will data on nuclear spectra, being gathered today, eventually lead to a comprehensive theory of nuclear structure.

Nuclear spectroscopy makes use of high-energy particles or electromagnetic radiation to excite the nucleus to a higher-energy state. The compound or excited nuclei formed in these processes are generally unstable and decay with the emission of nucleons, alpha particles, electrons, or electromagnetic energy (protons). In a given reaction, the determination of the type of emission and a measurement of its energy can be used to calculate the excitation energy required to excite the nucleus to the new level. By a series of such measurements, the possible energy levels for a given nucleus can be defined and, to some extent, the probable energy levels of the individual nucleons determined.

Van de Graaff Accelerators

Nuclear energy levels occur at energies from about 0.1 Mev up to more than 20 Mev. The energy and width of these levels must be measured with the greatest possible precision to provide a detailed picture of nuclear structure. In the energy range of which it is capable, the Van de Graaff® type of particle accelerator is the most useful for precision nuclear spectroscopy. This type of accelerator has a wide, continuously variable energy range and can produce high-intensity beams of particles which are mono-energetic to within a few tenths of a percent. Special techniques, such as those recently developed at Duke University, have shown that an energy definition of the order of 250 electron volts can be obtained with bombarding particle energies of several Mev.[1] With this resolution, line widths can be determined accurately and even the Doppler broadening caused by the thermal motion of the target nuclei may be taken into account.

A New Van de Graaff

Van de Graaff accelerators presently in use for precision nuclear spectroscopy are capable of accelerating particles to not much more than about 6 Mev. Very recently, a new machine of this type, called the Tandem Van de Graaff®, has been developed by High Voltage Engineering and is now producing protons with energies of more than 10 Mev with the expectation that 12 Mev will eventually be achieved. The accelerator, based on a principle first proposed many years ago by W. H. Bennett of the Naval Research Laboratory, extends the range of Van de Graaff accelerators so that more than twice the present number of energy levels may be studied by the methods of precision nuclear spectroscopy.

Even with these new techniques and machines, nuclear spectroscopy has far to go before it achieves the accuracy and completeness of atomic spectroscopy. As the amount of data on nuclear energy levels grows, the need for techniques of greater precision and for extensions to even higher energies becomes apparent. Nearly all the major nuclear physics laboratories of the world are studying nuclear energy levels. Most of them are using Van de Graaff accelerators in this great effort to unlock the secrets of nuclear structure.

Reference.
1. Bull. Am. Phys. Soc., 3 164 (1958)

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