

PHYSICS

Experimenting With Millions of Volts

In Recent Laboratory Experiments Man Speeds Electrons Within One Per Cent of Einstein's Ultimate Velocity

By WATSON DAVIS

MILLIONS of volts, more electrical pressure than man ever produced before are being used by science in an attack on problems that lie at the very heart of physics and medicine. Millions of volts may explore the heart of the atom. They may bring a new treatment of cancer.

In at least four great laboratories, in Berlin, Pasadena, Schenectady and Washington, a friendly race is in progress to build larger vacuum tubes that operate at larger voltages and produce more intense radiations.

In the laboratories of the Carnegie Institution in Washington there work three physicists. They are at present out in front in this race for more intensive radiation. These three are Dr. M. A. Tuve, L. R. Hafstad and Odd Dahl, of the staff of the Department of Terrestrial Magnetism of the Institution.

Their tubes have operated at about 2,000,000 volts, they have generated sparks at 5,200,000 volts and they have a new method that promises much higher voltages.

Out of their tubes come the most penetrating radiation that man has ever made. It is more penetrating, more powerful, more capable of harm or good, than radium, wonder element. Judged by the possible usefulness of the radiations, the achievements of these experimenters in the forefront of physics are believed by many to be more important than would be the artificial manufacture of radium itself.

The new tube can duplicate the radiations from radium and deliver three kinds of synthetic radium radiations just when and where desired. Radium, the chemical element which, when isolated by the Curies just before the turn of the century, upset the idea of the permanency of matter, produces its radiation continuously and nothing that can be done to it changes its rate of disintegration and its shooting off of powerful rays.

The three kinds of radium radiations have been christened with the Greek letter names, alpha, beta and gamma.

Alpha rays are made up of hearts of helium atoms, positively charged, rushing along at high speed. Beta rays are electrons that are speeded up. These can be thought of as gobs of negative electricity, weightless, but the very essence of matter. Gamma rays given off by radium are not particles at all but true waves like radio, light or X-rays. They are nature's X-rays, with shorter wavelengths, higher frequencies and more penetration into solid matter than the ordinary X-rays used by physicians and scientists. The new super-X-ray tubes, in effect, create synthetic gamma rays.

Achievements of Others

Others have been in this high voltage race. Almost simultaneously with Dr. Tuve's measurement of the speed of his beta rays and penetrating power of his gamma rays, there came from Berlin the announcement of a similar feat by Drs. A. Brasche and F. Lange. These workers have also performed the feat of giving to electrons jolts amounting to more than two million volts.

And other workers have not been idle. Using apparatus like the usual X-ray tube, Dr. C. C. Lauritsen and his associates of the California Institute of Technology, Pasadena, have recently produced X-rays from electrons speeded by more than 600,000 volts. Dr. W. D. Coolidge of the General Electric Company, using a tube of his own design called a "cascade" tube, has produced 900,000 volt electrons. Though these latter rays are not so speedy as Dr. Tuve's, they have much greater total intensity. More elaborate protection is required for workers.

To speed up immensely a wandering electron it is simply allowed to fall. But instead of a gravitational pull, an electrical pull is required. It is to produce this pull that the immensely high voltages are needed. A falling electron is much like a falling brick. The farther it falls the faster becomes its speed. An electron that has fallen through two million volts requires vigorous stopping. It is speeding along at the rate of 184,000 miles per second. This is the first time such velocity, only one per cent. slower than the fastest

speed possible, the speed of light, has been achieved by man. Einstein holds as a central point of his relativity theory that nothing can surpass the speed of light.

Imagine a brick that has fallen from the top of the Empire State building. It will make quite a commotion if it hits anything and will be badly smashed. As an electron cannot be broken up it sets up a very violent vibration in the atoms of any target which has been placed in its path. These vibrations travelling out through the ether constitute the X-rays which have the power to penetrate ordinarily opaque matter.

The X-rays are thus not material particles but a wave motion similar to light waves. The ether vibrations produced in these new experiments are also similar to light waves but of shorter wave-length, of greater energy and greater penetrating power than ordinary X-rays. They can pass through three inches of lead, the most opaque substance for such radiations. These waves imitate, in all essential respects, the gamma radiation from radium.

Innovations in cancer treatment are one possible outcome of the new gamma rays, for it is this constituent of the radium radiations that is effective in



THE WINNERS

In the friendly race. Left to right, Dr. M. A. Tuve, Dr. L. R. Hafstad and Odd Dahl of the Carnegie Institution of Washington watching artificial radium rays emerge from their high voltage apparatus.

treating tumors. On the other hand the gamma rays can do incalculable harm. They produce serious burns in normal flesh exposed too long to their action. During the early days of pioneer work with radium and X-rays many workers lost their lives because the action of the rays is delayed and fatal doses had been given before the danger was realized.

Just how much risk Tuve, Hafstad and Dahl are taking in playing with such a dangerous radiation machine is still a matter of conjecture. Dr. Winifred Whitman of Johns Hopkins University has been collaborating with the trio of physicists on this aspect of the problem. As she happens to be Dr. Tuve's wife, she will probably see to it that he does not run unnecessary risks.

An explosion that will wreck this corner of the universe is another possibility contained in this pioneering research of the three Washington scientists.

They plan to produce the most powerful projectiles ever launched by human ingenuity. They plan to attack the heart of matter itself, the atomic nucleus. They will bombard it with very speedy hydrogen atom hearts, brothers in radiation to the alpha rays from radium. This may tap the internal energy of the atom.

Atomic Explosions

Startling consequences may be forthcoming if direct hits are scored upon the atomic nucleus in such a way as to change the atomic heart into a new kind of atom, provided certain scientific theories are correct. Immense amounts of energy might be liberated. This would attack other atoms and set up a chain of explosions, growing in violence until there would be a new star in this part of the heavens. The earth and all its inhabitants would be consumed by the heat created, and that would be the end of the world so far as human beings are concerned.

Most physicists today do not believe that there is much probability of world disaster following in the wake of the atomic researches now in progress. They see instead a new opportunity of discovering what is within the atom.

New apparatus of comparative simplicity now being perfected by the three X-rayteers promises to produce ten or more million volts capable of being applied to X-ray tubes. With such enormous electrical pressures, there can be created streams of atomic projectiles unrivaled here upon earth.

The vacuum tube used in the Carnegie Institution experiments is similar

in principle to the widely used X-ray tubes, which have been of such immense importance in medicine, in industry and in the physical laboratory. The design of the tube uses a principle due to Dr. W. D. Coolidge of the General Electric Company, who has made important contributions to the same problem.

Until recently the highest electrical pressure that had been impressed on an X-ray tube was about 250,000 volts, although the production of one million volts had been successfully accomplished.

The contribution of the Carnegie Institution physicists to the problem is twofold. They have devised ways of raising the greatest attainable voltage to dizzy heights and ingeniously solved the problems of applying these enormous pulls to a tube from which the air has been pumped. The apparatus which makes this possible occupies a building about 25 by 50 feet.

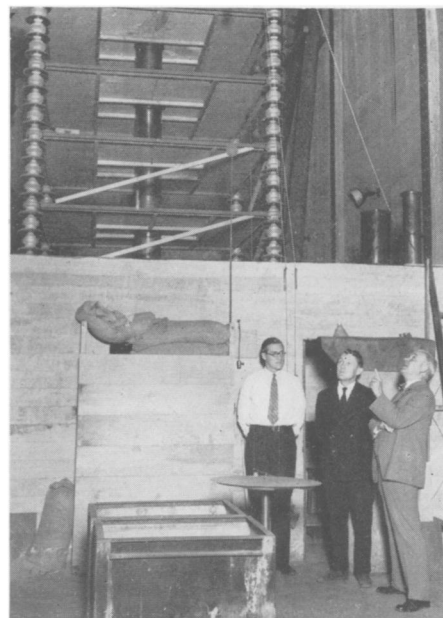
The attainment of voltage of from one to five million of short duration was completed as much as four years ago, in the early stages of this research. A modification of the so-called Tesla coil was used. This consists of a large coil of a few turns and a smaller one of many turns, both wound on the same axis. Like a step-up transformer or the more homely spark coil it converts an alternating voltage of low value into a much higher alternating voltage.

The primary coil of the Tesla set-up was supplied with the damped oscillatory discharge from a circuit containing a spark gap and a huge condenser consisting of glass plates about four feet square. The secondary coil of the Tesla, consisting of many turns of fine wire, is wound directly around the vacuum tube in which the electrons are driven up to their speed limit.

To aid in the insulation, both the coil and the tube are immersed in a large tank of oil about eight feet deep. At the highest voltages the coil and tank are subjected to a pressure of thirty-three atmospheres, which still further improves the insulation.

The electrons, instead of being given one big push, are given a series of smaller equal jerks as they progress down the tube toward the outside of the tank, where the experimenters are waiting for them with a magnetic device which measures their speed.

Previously Dr. C. C. Lauritsen of the California Institute of Technology had applied 750,000 volts to a gigantic X-ray tube by means of a transformer and standard X-ray technique. Dr. Coolidge



SANDBAGS AND CONCRETE

Protect scientists at the California Institute of Technology, Pasadena, from the high power X-rays of this 700,000 volt apparatus. Left to right, Dr. R. E. Vollrath, Dr. C. C. Lauritsen, designer, and Dr. Robert A. Millikan, Nobel prize physicist.

had successfully applied 900,000 volts to one form of his cascade tube about two years ago.

Dr. Lauritsen's tube is more nearly similar to the usual X-ray tube and not so revolutionary in design as the one in Washington. Much more power, however, is associated with the rays from the Pasadena apparatus, and therefore more protection is required for the scientists working with it, as may be judged from the concrete wall that surrounds the tube.

Dr. R. A. Millikan, under whose direction this work was carried out in California, has estimated that their tube would produce rays equal in intensity to those from twenty pounds of radium. That is about fifty times as much as all the purified radium available in the world. Twenty pounds of radium would be worth about five hundred million dollars.

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Rainbows entirely red in color are sometimes seen when the sun is close to the horizon and when the air is dust-laden.

The rhinoceros though heavy is a remarkably agile beast.