THE ORIGINS OF THE PROXIMITY FUZE

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Abstract

The poor quality of antiaircraft artillery in 1940 could be traced to the uncertainties in determining the range to the target and in setting a time fuze accordingly. The proximity fuze eliminated these problems by sensing the presence of the aircraft.

Development at DTM

In 1939 the distressingly poor accuracy of heavy-gun antiaircraft artillery led many to discount it as a weapon of consequence. Most outspoken of these critics were Lord Cherwell, Churchill's science advisor, and air-power prophet Billy Mitchell, who repeatedly said the weapon was absolutely worthless and incapable of improvement. Concern in Great Britain nevertheless initiated some attempts to remedy this by fuzes that sensed the presence of an aerial target. Although these studies were given low priority, they did furnish the circuit that was brought to the U.S. by the Tizard Mission in September 1940 and given to the group at the Department of Terrestrial Magnetism (DTM), Carnegie Institution of Washington that had begun to address the same problem independently only weeks before, strongly encouraged by the U.S. Navy, which did not share the attitudes of the AAA critics. The DTM group, led by Merle Tuve and ably assisted by Richard B. Roberts, Lawrence Hafstad and soon many more, were convinced that whatever method was selected it would require electronics. By the time the British mission arrived they had already begun firing vacuum tubes from a small cannon and had learned that they frequently survived the ordeal.

Both the Americans and the British

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considered the same possible approaches: (1) a radio fuze that would sense the presence of the aircraft, (2) a radio fuze tracked by the AA gun's radar that would be triggered from the ground when its range was the same as that of the target, (3) an acoustical fuze actuated by the dominant resonances of the aircraft's engines and propellers, and (4) an optical fuze actuated by the appearance of a photoelectric current with the frequency given by the projectile's rotation. Roberts made a copy of the Tizard-Mission circuit the day after receiving it, and its performance so impressed the group that this approach gained high priority, especially as it showed promise for miniaturization.

The basis of the fuze was an 80 MHz, free-running Hartley oscillator with its output connected between the body of the projectile and a metal nose cone. The plate current was connected through a low-pass filter to a two-stage audio amplifier. The non-radio-frequency component of this current changed when an object entered the near-field of the radiation pattern, and this change, which contained the Doppler frequency describing the relative motion of projectile and target, was amplified and applied to a thyratron, whose conduction exploded the shell. The designer of the circuit was the New Zealand born W.A.S. Butement, one of Britain's best radar engineers.

Roberts completed successfully two simple experiments within 48 hours of hearing about the Navy interest in a fuze, which gave the group sufficient optimism for electronics surviving the acceleration of an artillery shell. He mounted a conventional tube on a lead brick to test it on a ballistic pendulum, then dropped one mounted on a hemisphere of lead from a building roof onto a steel plate, which allowed the calculation of the acceleration on impact from the deformation of the lead. Tests were quickly extended to a centrifuge and to a 37-mm gun, which fired test-loaded projectiles vertically on a farm near Vienna, Virginia. The test functioned on both the ascending and descending courses -- the latter causing nervousness among the testers until they learned to predict the drop point accurately. With this background the performance of a lash-up of Butement's circuit in the laboratory gave the group tremendous confidence. The small movement anywhere in the room of a brass rod cut to the dipole length of the transmitter caused a relay controlled by the circuit to shut.

On 20 April 1941, 35 weeks after the beginning of the project, an oscillator was fired from the gun, and its radiation picked up on a communications receiver. By August 1941 a complete pilot production fuze was successfully fired at the Navy's Dahlgren testing grounds.

Applied Physics Laboratory

By spring 1942 the number of persons working on the project in the Cyclotron Building at the Broad Branch Road grounds in Northwest Washington had outgrown the available space, so a garage was rented in Silver Spring, Maryland to accommodate operations. The Carnegie Institution did not want to continue as the contracting agency for the project, and a new organization was formed, the Applied Physics Laboratory with the Johns Hopkins University sponsoring the work. Tuve became the first director.

As soon as it was clear that vacuum tubes could stand the hostile environment of an artillery shell, contracts were let to Sylvania for the design of very small tubes with strengthened electrode structures (the glass envelopes were never problems) and with suitable electronic parameters. Batteries proved to cause more problems than tubes. Dry cells deteriorated so rapidly in storage that they were replaced with acid cells. In these the acid was released from a glass ampule that shattered on firing and was spun into the electrodes. The general design elements became obvious very early, and Tuve decided to initiate production contracts before prototypes were satisfactory.

On 12 August 1942 test firing over the Chesapeake Bay from USS Cleveland at radio controlled targets brought down the only two available targets, each on a single approach. On 5 January 1943 USS Helena brought down a Japanese bomber on the fifth round using an industrially produced fuze, 28 months after the initiation of the project.

This unprecedented success and speed resulted from careful testing of the components that manufacturers furnished from the proto-production lines, which allowed production on a large scale when the first design was complete. Quality control was perhaps the real secret of success. Several fuzes from each new batch were test fired, and the batch rejected, if the dud rate was unacceptable, generally sought to be less than

5%, although it was difficult to maintain this standard. Tuve insisted that the fuze be bore safe and incorporated seven safeties to achieve this.

Field artillery had long used time fuzes for producing air bursts over ground targets, a method that required visual observation and relatively flat trajectory guns for accurate placement. The Army's light artillery had changed from flat-trajectory guns to howitzers in order to use heavier projectiles, which frequently descended at steep angles, boosting the accuracy requirements for setting time fuzes in order to secure bursts at the 20 meters required for effectiveness. It was a problem that affected all artillery fire at extreme range. Many targets could not have the critical height of burst adjusted by observers, and night and fog prevented observation in any event. These onerous restrictions were removed with the proximity fuze.

It was quickly realized that different kinds of guns and different kinds of service required fuzes to be accordingly adjusted. Initial designs, intended for high-velocity AA guns, depended on the large, fixed acceleration for proper fuze operation, whereas fuzes for howitzers, which have lower, variable muzzle velocities, required corresponding changes. The distance from the target at which the shell exploded depended on the kind of target with different parameters for antiaircraft and field artillery. The small size of the German V-1 flying bombs required fuzes adjusted correspondingly. They were tested on mock-ups based on intelligence reports in time for effective engagement.

Britain continued its proximity fuze work but did not achieve a production fuze. Fuzes for British guns were included early in production schedules. Eventually 30 fuze types were manufactured for Allied artillery.

National Bureau of Standards

Early in the project it was decided that there were significant design differences between rotating and non-rotating projectiles, and the latter problem was given to the National Bureau of Standards. Designs for AA rockets provided difficulties resulting from various modes of vibration and from the need to use a wind-vane driven generator for power rather than batteries.

Epilogue

The fuze was widely used in the Pacific War beginning in 1943 and helped transform the air defense of surface ships beyond what an immoderate optimist would have dreamed possible in 1939, and was one of several factors that completely changed the nature of war at sea. Surface ships proved repeatedly that they could protect themselves against heavy air attacks. Radar-controlled guns with fuzes were the second of the three gauntlets that Japanese planes had to run in their disastrous defeat at the Battle of the Philippine Sea in June 1944, the first being the radar-arranged ambushes by fighters and the third the close-in defense by automatic guns. Until December 1944 use in the European theater was restricted to locations that allowed no duds to fall into enemy hands. Along with the SCR-584 tracking radar and the M-9 electronic analogue director, it was crucial in the spectacular defeat of the V-1s in 1944. It received due honors for its contribution to the defeat of the German ground forces in the Battle of the Bulge when applied to infantry advancing under cover of fog.

A total of 22 million fuzes were manufactured. By 1945 the production of tubes for proximity fuzes was 400,000 per day with 95% from Sylvania.

After the war Tuve and Roberts returned to DTM, which went back to the style and size of its pre-war operations. Hafstad remained for a time at APL as Director.

Appendix: The German Effort

In the summer of 1939 Cobden Turner, owner of Salford Electrical Instrument Company (British), and a few of his engineers visited Siemens und Halske (German) on business and got a hint of fuze work being done there. Later in the year two anonymously written letters purporting to summarize German technical weapons arrived at the British Embassy in Oslo and described the fuze, even enclosing one of the miniature tubes being used. The design attempted to utilize the change in electric capacitance between a nose electrode and the shell body when some object came near.

Siemens und Halske dropped work on the fuze, but others took up the task later in the war when large antiaircraft rockets were being designed at Peenem•nde. A proximity fuze was necessary for these, but it was not subject to the severe constraints of space and shock resistance imposed on the fuze of an artillery shell. The work was directed from Peenem•nde West and was both of local and contracted origin. Four fuzes underwent simultaneous development. One was acoustical, two were decimeter cw radars, and the fourth used the Butement antenna loading idea at 100 MHz but with a dipole antenna. These competing designs were tested on the ground at Peenem•nde but never reached production or even prototype testing in rockets.

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