A Study of Wire-Deploying Devices Designed to Trigger Lightning

VERNON J. ROSSOW,* HAROLD G. CLEMENTS,† and B. PAT DENARDO‡
NASA Ames Research Center, Moffett Field, Calif.

Theme

METHODS were explored for deploying wire from rotating gun-launched bobbins and from nonrotating rocket-launched bobbins as a research tool in the study of atmospheric electricity and as a possible means for reducing lightning hazard to tall rockets during fueling and during ascent from the launch pad through storm clouds that may be in the area. The objective was to develop a device that would deploy a steel wire (0.13 or 0.20 mm diam and more than 1 km long) in one piece along a trajectory through the atmosphere at a velocity of 150 m/sec or greater. In brief, the gun-launched devices functioned satisfactorily in that they met most of the objectives; however, only partial success was achieved with the rocket-launched devices.

Contents

In the past, rope or wire has been thrown or pulled over substantial distances by rockets or gun-fired projectiles for many reasons. For example, linethrowing devices have been used by the U.S. Coast Guard for some time for rescue and salvage of vessels and on occasion for setting up communication systems. Of interest here is the use of vertically deployed wire to initiate lighting. One technique, developed by the Lightning and Transients Research Institute[1] uses a small Coast Guard Rocket to tow a steel wire aloft from a cannister on board a metal ship off the Florida coast. About 200 to 300 m of fine wire are deployed toward a cloud in about 1 sec. The lightning follows the spiral shape of the wire back to the ship so that measurements can be made of the characteristics of the stroke. The deployed wire serves only as a trigger to initiate a lightning stroke. The discharge process begins with an initial surge of current along the wire that vaporizes and ionizes the metal wire and some of the surrounding air. The substantial current path thus provided conducts the remainder and largest part of the electric charge. When the current decreases, the ionized channel cools, and the charge transfer process ends.

The work reported in this paper was initially motivated by a study of the possibility that atmospheric vortices such as waterspouts and tornadoes might be identified, controlled, or modified by electricity in the parent cloud. This possibility, however, appears to occur only on a random basis at best, as indicated by measurements on a number of waterspouts,[2] so the wire-deploying study was directed at obtaining a device to trigger lightning for research and protective purposes. The lightning strikes to Apollo 12 during launch[3] added motivation to the development of a wire-deploying device that might be used to discharge electrified clouds in a harmless way when a launch must be made in unfavorable weather.

Since the purpose of the deployed wire is to initiate lightning, the backup paper (see footnote at beginning of Synoptic for availability) contains information relating to the nature of lightning and to various methods for generating strokes and arcs. One of the more important design considerations appears to be that the likelihood of a strike is increased considerably by thrusting a wire or long conductor rapidly into the electrified region.[4] Therefore, a requirement was made that the approximately 1 km of wire to be deployed at a velocity of 150 m/sec or greater. Since the resistance of the air is large on long lengths of wire being towed by an airborne device from a stationary bobbin on the ground, it was also decided that the wire should be dispensed from the moving vehicle to permit the use of longer lengths of wire and higher deployment speeds. This technique is used to deploy two wires from the TOW missile (developed by Hughes Aircraft Co. in Tucson, Ariz.) so that electrical communication can be maintained at speeds up to 400 m/sec over horizontal distances up to about 3 km. Much of the information and technology used on the TOW bobbins by Hughes was adapted to the study reported here.

Rotating gun-launched bobbins: Initial tests were conducted with rifled 37 and 40 mm cannons (standard field weapons modified for laboratory use) because the size of the projectile was such that more than a km of 0.20 mm wire (about 0.45 kg) could be easily wound onto a recess on the body without coming in contact with the barrel and because the gun size did not exceed the capacity of the range. The projectiles have a blunt nose with a recessed hole for the tailstock centerrest to facilitate machining the body and winding the wire on the recessed area. Each layer of wire was wound onto the recessed section in the center with about 0.5 kg tension and held in place with a clear acrylic spray (suggested by Hughes) that was allowed to dry, with the aid of a lamp, before the next layer was applied. In this way, a combination of wire and acrylic plastic was built up in the recessed part of the projectile so that the wire was held securely in place until it was torn out of its position by the deployed wire.

A typical test round contained about 100 m of wire, weighed from 0.3 to 0.5 kg, and was fired at a velocity between 450 and 1000 m/sec. When the projectile was loaded into the gun, the free end of the wire was placed in the groove on the borrelet ring. When the projectile left the gun barrel, centrifugal and air forces pulled the loose end of wire off the bobbin to begin deployment. As more wire was spun off, the deployed wire coasted downrange and the projectile slowed gradually, because of air drag, so that the wire eventually comes nearly to rest. At 45–150 m downrange, depending on the type of test, the bobbin impacted into a catcher made of styrofoam and cotton wadding. Photographs taken during flight (Fig. 1), the imprint made by the wire on the catcher face, and the sequence in which the wire pulled off the catcher face after the test, showed that the deployed wire was thrown off at the start of the trajectory as planned. Furthermore, as more wire was spun off it formed a long spiral that was centred on the projectile, about bore size at the base of the projectile, and enlarged continuously to about 1 m diam at the free end of the wire. Superimposed on these spirals was a

Received December 20, 1971; revision received May 15, 1972. Full paper (NASA TM X-62, 085) is available from National Technical Information Service, Springfield, Va. 22151 as N71-36772 at the standard price (available upon request).

Index categories: Aircraft Rocket Applications; Atmospheric, Space, and Oceanographic Sciences; Safety.

* Staff Scientist. Associate Fellow AIAA.
† Aerospace Engineering Technician.
‡ Research Scientist.

smaller set of waves or spirals that was attributed to the initial configuration of the wire on the bobbin core. During this first 45–150 m part of the trajectory the length of the deployed wire was about one-third of the flight path. On some rounds the recovered bobbin could simply be cleaned and fired again since the remaining wire layers were held in place by the acrylic spray even at the approximately 100,000 g load experienced during launch in the gun barrel and during deceleration in the catcher.

When the 40 mm design was fired over the outdoor range, the launch angle was raised from 0° to about 10° to provide a nonwire-deploying trajectory of about 2000–3000 m. It was found that when wire was deployed, the free end, or beginning, of the wire came to rest at 500–750 m from the gun while the projectile landed at 1000–1500 m. The reduced distance to impact was caused by the so-called deployment force of the wire on the projectile (or bobbin). This was the force required to pull the wire out of its wound position over the rear borrelet ring or flange thereby decelerating the wire from the projectile velocity to the lower velocity of the deployed wire through the air. As more wire was laid along the trajectory, the wire slowed toward zero velocity requiring a faster deployment rate that in turn caused a larger force on the bobbin. In the rounds fired, the deployment force was enough to reduce the trajectory to about one-half that of a nonwire-deploying round. All other aspects of the wire deployment were felt to be acceptable.

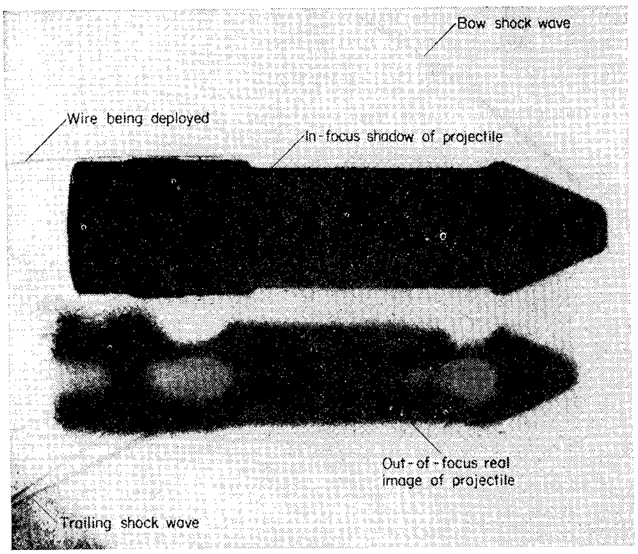

Fig. 1 Aluminum bobbin for 40-mm gun in flight (velocity = 820 m/sec) as 0.20-diam wire is deployed.

The experience gained from the 37 and 40 mm tests was then applied to the 3-in./50 caliber guns carried on U.S. Coast Guard cutters.[2] The limited tests carried out on this device indicated that it worked as planned and that it would deploy wire at speeds up to about 850 m/sec. Once again the trajectory was shortened by the deployment force of the wire.

Nonrotating rocket-launched bobbins: The development of a rocket-launched bobbin was undertaken to provide a low cost and more mobile device. The 2.75 in. Folding-Fin-Aircraft Rocket (FFAR) was chosen because it was readily available, inexpensive, and could be fired from the vertical to horizontal direction both from the ground and from an aircraft. Also, it had a detachable head that could be removed and substituted with a wire-deploying head. Although the specified objectives were not achieved with the rocket head, it was found that wire could be deployed from inside the bobbins at speeds up to 90 m/sec with negligible deployment force and that coils or bobbins could be made to deploy from the inside and to withstand the approximately 70 g load of a rocket during launch. (See full paper for construction details.) It was also found that the free end of the wire could be tied directly to a point at the launch site or it could be made to release at about 300 m downrange. In either case, only 15–60 m of wire (depending on the binder used to make the bobbin) was deployed before the wire was permanently deformed into a sequence of curls and loops that tightened into kinks causing the wire to break. The first part of the wire deployed as planned and the undesirable loops were present only in the last 2–3 m. The rocket velocity at the time of wire breakage was estimated at 75–90 m/sec in the cases where deployment was started at the launch site. Various schemes were tried in an effort to eliminate the wire kinking problem but none were successful so it was concluded that deployment of wire from the inside of bobbins in this device would not work consistently above about 75 m/sec.

References

[1] Newman, M. M., Stahmann, J. R., Robb, J. D., Lewis, E. A., Martin, S. G., and Zinn, S. V., "Triggered Lightning Strokes at Very Close Range," *Journal of Geophysical Research*, Vol. 72, Sept. 1967, pp. 4761–4764.

[2] Rossow, Vernon, J., "Observations of Waterspouts and Their Parent Clouds," TN D-5854, 1970, NASA.

[3] Staffs of NASA Marshall Space Flight Center, NASA Kennedy Space Center, and NASA Manned Spacecraft Center, Analysis of Apollo 12 lightning incident, MSC-01540, Feb. 1970, NASA.

[4] Brook, M., Armstrong, G., Winder, R. P. H., Vonnegut, B., and Moore, C. B., "Artificial Initiation of Lightning Discharges," *Journal of Geophysical Research*, Vol. 66, Nov. 1961, pp. 3967–3969.