Photographing of High Velocity Phenomena

How Wave Motions of the Air are Caught by the Camera

By William Albert Hyde

IN previous issues of the SCIENTIFIC AMERICAN have appeared photographs of the waves created in the air by the passage of projectiles at high velocities. Inasmuch as these are invisible disturbances of an invisible medium, some readers may have been considerably puzzled to account for their photographing. The solution of the mystery is at once simple and highly interesting. The whole process depends entirely upon the refraction property of light.

Methods of obtaining photographs of such wave disturbances are various. The apparatus for one of them is shown in Figs. 1 and 2. In Fig. 1, M is a concave spherical mirror, S and G are spark gaps in the same circuit, C is the camera. The circuit is closed by the passage of the bullet through G, being so arranged that the resulting spark discharge at S is not instantaneous, but is subject to a definite time lag of about $1/2,000$ of a second. The flash of this spark is reflected from the mirror back through the medium, disturbed as it is by the passage of the projectile; and the irregularities in density of that medium due to the presence of the waves lead to refraction of the light thus passing through. This refraction causes the light from the spark to be piled up in parts of the plate and thinned out in others, producing, of course, a photographic image of these invisible disturbances.

The arrangement of the electric circuit affording the time lag necessary to prevent the spark reflection from passing back in front of the wave-head is rather ingenious. There are three oscillatory circuits (Fig. 2), charged in parallel by a static machine at G; L is a variable inductance and R a very high resistance, preferably a tube of slightly salted water. R permits the charging up of C_2 and prevents its discharge except at the proper time through S. The circuits are all made up of short thick copper wire. The period of I is shorter than that of II, and by strong damping I can be made to discharge before II begins. There results a high difference of potential between m and n, and the voltage across S rises. With the gap at S of proper length, III will discharge when II has made one half-oscillation, which can be varied at I.

Another method, not so precise in locating the bullet but simpler as far as the electric installation is concerned, is that of Fig. 3. C_1 is a large and C_2 a small condenser, S the photographing spark gap, R a high resistance, T a tube connected to a ring A through which the bullet passes, F a gas flame, D a disk with a hole through it. As the bullet passes through the ring a wave traverses the tube and blows the ionized gas through the hole in the disk to the other terminal, thus triggering off the spark at S. The small condenser C_2 is discharged at once, but the resistance R prevents the discharge of C_1 until the difference in potential at S is great enough to break down the gap. The actual work of photographing is accomplished as in the previous case; the apparatus for this is not shown in the present figure.

The results of these methods, as may be seen from the large photograph of a bullet at 2,700 feet per second, are singularly beautiful. Some idea may be formed of

Bullet and accompanying waves, photographed with apparatus of Fig. 1

Fig. 1. Apparatus for air-wave photography

Fig. 3. Simple device for wave photographs

Fig. 2. Electric circuit used in apparatus of Fig. 1

Fig. 4. Third type of apparatus

Fig. 5. Circuit for use with apparatus of Fig. 4

Projectile and waves, photographed with apparatus of Fig. 4

the variation in intensity of the front wave from the way the wave shades off. It is rather surprising that such a well defined tail wave is found. The wake at the rear is not smoke, as might appear at first glance, since this type of photograph shows only the variations in the refractive index of the air. It is probably due to the vortex motion of the air rushing in to fill the vacuum; for it has been shown that there is a vacuum at the base of a projectile moving at such velocities as those we are dealing with. During this process the air is heated, with great change in density and refractivity; hence the recording in the photograph of this feature.

The apparatus described is expensive and difficult to obtain. Similar results may be obtained by means of the apparatus shown in Fig. 4. B is a light-tight box, hooded at the ends to prevent light from the bullet holes falling on the plate. S is the spark gap and w, w the wires shortcircuited by the bullet. There is no camera or mirror, the light from the spark passing through the waves and falling directly upon the photographic plate P. The circuit is shown in Fig. 5. The lettering corresponds to that in previous

diagrams. S' is an additional gap, enclosed, so that C_1 has to discharge through two gaps in series. The condensers are charged to the desired potential, which is less than that required to jump both gaps in series. If one gap, S', can be shortcircuited, then C_1 will discharge through S, the photographing gap. This is accomplished by means of a secondary circuit through S', C_2 and G. When G is closed by the bullet, C_2 discharges through S' and hence C_1 through S. It will be noted that this gives purely an outline picture, in contrast with the previous methods.

The question suggests itself, whether application cannot be made in the arts and sciences, in research or invention, of these methods. In photographing a bullet, for instance, a movement of $1/100$ inch would show a blur on the negative. At a velocity of 2,700 feet per second it would therefore be necessary, under ordinary methods, to have an exposure of

$$\frac{1}{2,700 \times 12 \times 100} = \frac{1}{3,240,000}$$

second, in order to get a clear image. This is, of course, out of the question; hence a study of such high velocity might find an application for the methods under discussion. These methods seem applicable for work on air or gases, where the index of refraction is considerable, or even in lesser degree on liquids and crystals. A sound wave passing through a glass rod with velocity 5,000 feet per second has been thus photographed; and it is suggested that light might be thrown upon the theories regarding the formation and growth of crystals by this means.

It is clear that a point source of light is necessary; otherwise the well defined shadows will not be obtained. The range of the methods is surprising. The writer has used the scheme with 20 feet between spark and plate. The spark, projected across a gap of three quarters of an inch, looked to be about a half inch in diameter; but this is an illusion, as the pictures showed it to be virtually a point.