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SONIC BOOM EFFECT ON FISH – OBSERVATIONS

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ABSTRACT

Motion pictures of fish in a small tank at the time a bullet traveling 1200 m/sec passes a few centimeters above indicate that fish sense the passage of the shock wave but suffer no ill effects. The pressure rise at the bow shock wave was 0.26 atm or 275 times that associated with a strong sonic boom, for example, from the proposed supersonic transport.

During late 1970 and early 1971, there was considerable controversy about the Supersonic Transport (SST), much of which had to do with pollution in the atmosphere, surface noise, and, to a lesser extent, possible harmful effects to marine life from the sonic boom associated with the aircraft bow and trailing shock waves. With the last possibility in mind, and with a ballistic range at hand, it was a relatively simple matter to make a few tests firing a high velocity bullet over a small tank of water containing a few fish to determine any immediate ill effects on them. Sonic booms from present day aircraft have been occurring for some time and some certainly must have occurred over water but, to my knowledge, there have been no reports of deleterious effects on marine life.

The condition for supersonic flight of the SST flying at a Mach number of 2.7 was that the strength of the shock wave at sea level would be 95.7 N/m^2 (2 psf). Hayes (ref. 1) mentions shock strengths of from 1 to 3 psf for currently designed SSTs, constructed or proposed. In the present tests the pressure differential was about 26,300 N/m^2 (550 psf), 275 times greater than that of the SST. It had been intended to reduce this pressure differential to a lower value if the results warranted it. As will be mentioned later, the time duration of the N-wave pressure differential in the present tests was considerably less than for the case of the SST.

The tests were done in the Pressurized Ballistic Range at the Ames Research Center. A 0.220 Swift rifle with a standard bullet muzzle velocity of about 1200 m/sec (3900 ft/sec), corresponding to a

Mach number of 3.5, was placed so that the flightpath of the bullet was about 11-1/2 cm above the water surface. The water was contained in a 15-1/4 by 15-1/4 by 30-1/2 cm-long clear tank located about 20 m from the rifle. The fish were five guppies (Lebistes reticulatus), small but hardy tropical fish.

A few shadowgraph pictures were taken of the bullet and its shock wave impinging on the water surface. Since the shadowgraph picture was taken during an extremely short duration of time (less than a microsecond), it does not show reaction of the fish to the shock wave. Consequently, an 8-mm movie camera with a speed of 18 frames/second was also used to record the reaction, if any, of the fish. Because of space limitations the fish tank had to be moved away from the shadowgraph station to accommodate the movie camera. Since the framing speed is too slow for the camera to see the bullet in flight, a visual signal was needed to indicate when the bullet passed over the fish. Several were tried; a ballasted cork with upright fins that tilted slightly from the shock wave; a yaw card in the path of the bullet that showed the instant of bullet penetration; flames from ordinary birthday candles that flickered and bent in the flight direction but were not extinguished; and a 45° mirror that usually enabled the camera to see the gun muzzle flash or a portion thereof. The first two signals were visible to the fish but the latter two were shielded from them. The reaction of the fish, as will be discussed later, did not seem to be associated with any of the means used to detect the time of passage of the bullet. In addition to the shadowgraph and movie pictures, some observations of the fish behavior were made visually.

A shadowgraph picture of a bullet with its shock waves reflecting off the water surface is shown in figure 1. Since the optical system uses a conical light field, some explanation is necessary for proper interpretation. The two narrow black bands at the top of the fish tank are the two top edges of the tank. The wider black band just below is the water surface extending across the 14-1/4-cm width of the tank. No fish were in the tank at this time. For this case the path of the bullet was about 4-3/4 cm above the water surface. The leading shock wave impinges on the water surface halfway between where it is seen disappearing and then reappearing as a reflected shock wave. There is no appearance of the wave in the water. The angle that the leading shock wave forms with the water surface for both the incident and the reflected shock is about 19°. According to Cook (ref. 2) this angle is about 5° greater than the critical angle for the passage of a sound wave from air into water. Cook states that unless the horizontal speed of the shock wave is greater than the speed of sound in water the boom energy will be totally reflected, and the sound pressure in the water falls off with depth below the surface.

The movie film disclosed that the fish usually reacted, but not violently, to the shock wave or to its associated sound pressure. Fish near the surface reacted more than those near the bottom. This reaction consisted of a flinching type motion followed occasionally by a rapid movement, generally downward. Not always was there noticeable motion. In some cases several but not all the fish were seen to respond. When the fish did move, they did not appear to be alarmed, that is, they settled down immediately. In contrast, when the camera flood light was turned on, the fish would dart about rather excitedly for a few seconds. The guppy is a lively fish and will occasionally dart about for reasons known only to him. It was therefore necessary to rerun the movies several times before one was convinced that the passage of the shock wave was being felt. The fish still reacted in a control experiment when the tank was covered with a 5-cm layer of polyurethane foam, although the reaction was even less pronounced. Waters and Glass (ref. 3) in experiments using dynamite caps above water concluded that underwater sonic boom noise would be discernible only at very low frequencies and at shallow depth and that pressure fluctuation spectrum levels due to surface waves would be higher than levels due to sonic booms. Hayes (ref. 1) gives the acoustic energy transmission coefficient for air-water interface as about 0.001, indicating that sonic booms transmitted into the ocean should be very weak and not likely to be an important element in the marine environment.

Several tests were done to determine if sound alone would startle the fish. No reaction of the fish was observed from sound caused by a loud quick-opening valve activated just before a test, sound of pounding steel on steel a meter or so away from the tank, or sound of a 0.220 Swift blank that had the full powder load but no bullet.

Ripples on the water were not observed in either the shadowgraphs or movies when the bullet passed over. This observation tends to rule out any influence the wake of the bullet might have had on the fish. Even with the tank filled to its brim, no water splashed out or spilled over the sides.

The most obvious conclusion from these simple and largely qualitative tests was that none of the fish were killed or even stunned. It was further concluded that although fish react to the passage overhead of a strong shock wave, they do not suffer any harm. Whether or not the N-wave pressure differential is the most significant factor of the sonic boom is not known. It is likely that the duration of the N-wave is of considerable importance. For the 0.220 bullet used in these experiments the duration of the N-wave is about 50 microseconds, whereas the SST would produce one lasting a few tenths of a second. The guppies (two female and three male) had 18 bullets fired over them. The fish were kept isolated for observation for two months after the tests, but did not show any adverse effects. A more rigorous experiment involving fish would probably require that they be isolated from a control group and studied for several generations for any long-term ill effects.

REFERENCES

1. Hayes, W. D.: Sonic Boom. Annual Review of Fluid Mechanics, ed. M. Van Dyke, W. G. Vincenti, and J. V. Wehausen, Annual Reviews Inc., Palo Alto, 1971, pp. 269-289.
2. Cook, R. K.: Penetration of a Sonic Boom into Water. J. Acoust. Soc. Am., vol. 47, no. 5, Pt. 2, 1970, pp. 1430-1436.
3. Waters, J. F.; and Glass, R. E.: Penetration of Sonic Boom Energy into the Ocean: An Experimental Simulation. Hydrospace Res. Corp. Tech. Rep. No. 288, June 1970.

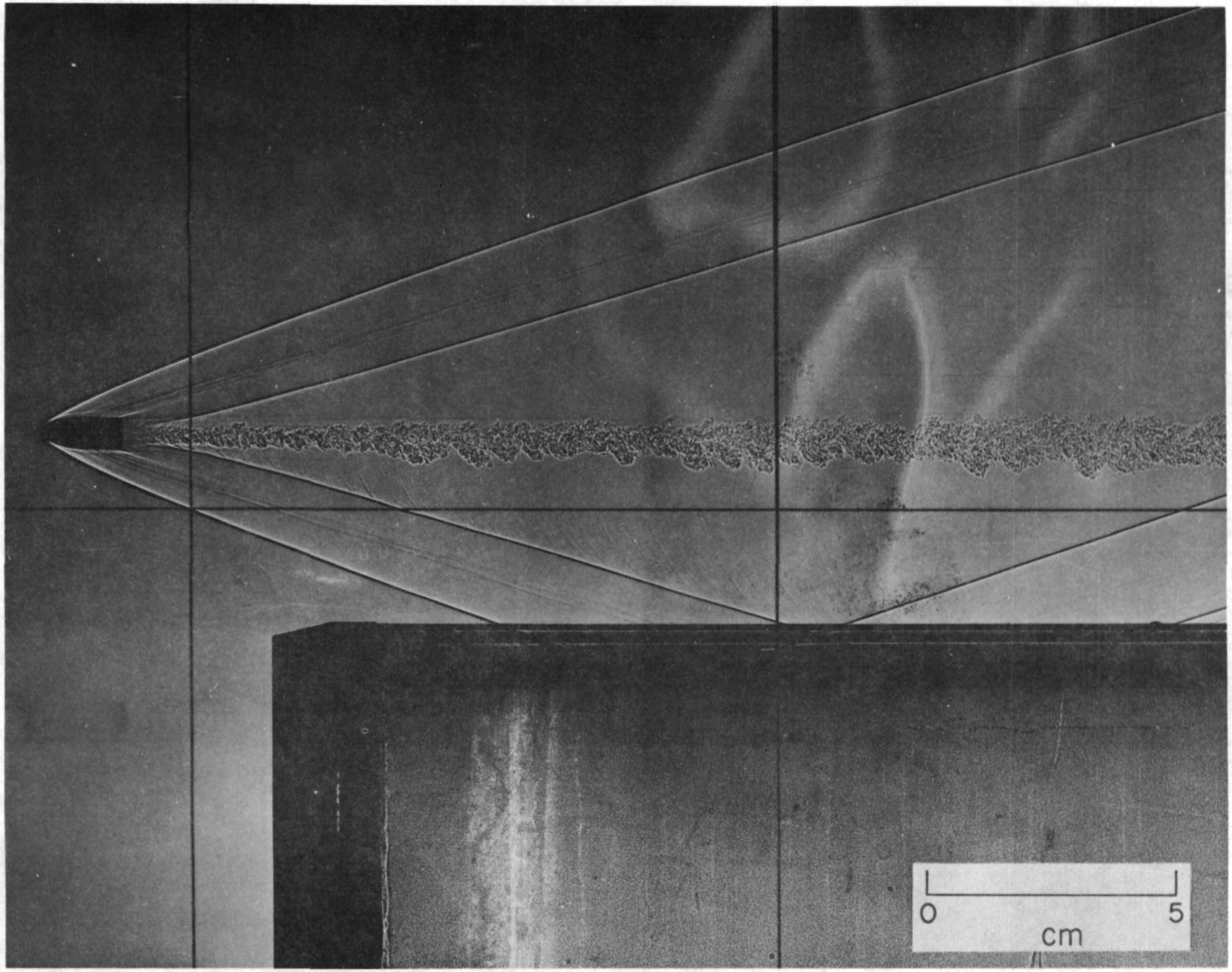

Figure 1.- Shock waves from 0.220 bullet impinging on water surface.