The Fastest Camera at Caltech

A Caltech engineer has designed an instrument which is potentially the world's fastest movie camera. A combination of speed and short exposure time, each independently controlled, makes the camera unique and increasingly valuable to research. A shutter speed of one 20-millionth of a second has already been attained, pictures have been taken at a rate of 1,000,000 frames a second, and there is a good possibility that even faster pictures may be taken in the future.

Adapting parts from radar apparatus, airplanes, and other handy sources, Albert T. Ellis, associate professor of applied mechanics at Caltech, designed this ingenious camera for the express purpose of taking photographs of cavitation bubbles that are born and die within a few thousandths of a second. These are the destructive bubbles which collapse and cause shock waves that lead to fatigue and eventual disintegration of metal in ship propellers, water pumps, and turbines in hydroelectric plants.

The camera is now being applied successfully to many other new problems requiring the observation of extremely fast phenomena. These include explosions, high frequency fatigue in aircraft metals and other materials, and stress and strain field propagation in metals.

The fast camera is proving particularly valuable in high speed impact research. Pictures are taken of stress waves traveling in metals subject to impacts. Such impacts may occur, for example, when meteor particles hit space vehicles. The waves are made visible in the pictures by bonding photoelastic materials to the metal surface. The 11,000 mile-per-hour speed of these waves makes exposure times of one 20-millionth of a second necessary. One of the tests involves firing a bullet at 6,500 feet per second into a solid block of ordinary gelatin – since current research indicates that very high speed impacts cause metals to behave like liquids.

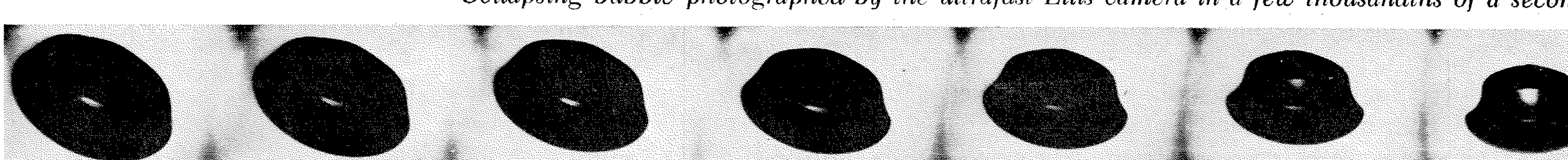
In another test, an air gun propels a hammer against a piece of metal, setting up sound waves. Just before hitting the metal, the hammer closes an electrical circuit and this sets off the camera, producing a picture at the exact moment of impact.

The camera stands about five feet high, including the table to which it is firmly bolted. It takes either 120 frames of 35 millimeter film at each loading, or 240 frames of film half that size. Because of the swiftness with which it goes through its sequence of pictures and the speed of the reactions it photographs, camera and reaction must be synchronized. This requires clever triggering devices.

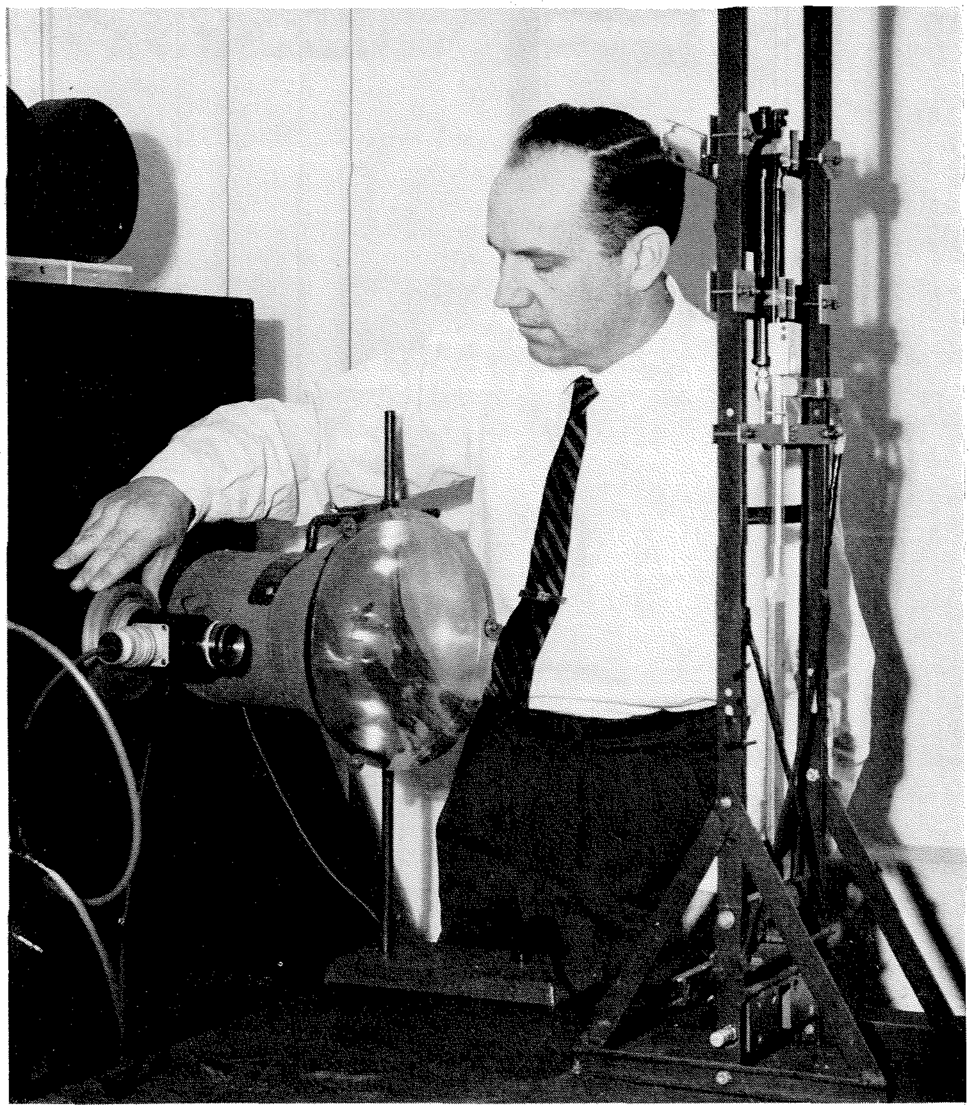
To capture cavitation bubbles, for instance, Dr. Ellis places a beam of light through water where the bubbles will form. Two photoelectric cells are out of line of the beam but close enough to pick up any light scattered from the beam by the forming bubbles. Picking up such scattered light by the photoelectric cells triggers the camera.

The camera has its own lighting system. A tremendous amount of illumination is required to expose film at such rapid speeds. A flash lamp is used that gives 60 times more total light than the most powerful flash bulb. About 6,000 volts of electricity are needed to achieve this brightness and the light is sustained

Collapsing bubble photographed by the ultrafast Ellis camera in a few thousandths of a secon



Albert T. Ellis, associate professor of applied mechanics, with the unique ultra-high-speed camera he developed for taking movies at the rate of 1,000,000 frames a second and faster.



for only about one five-hundredth of a second.

The shutter is capable of reacting at one billionth of a second. Since no mechanical shutter could achieve anything like this speed, it must be operated electronically. For this, an electro-optical shutter called a Kerr Cell is placed in the middle of the lens system, which consists of one or two optical lenses for focussing and two polaroid filters.

The first polaroid filter passes only light that is polarized in one direction. The second filter is turned so that this light will not pass until the Kerr Cell gives the light an additional rotation. The escaping light then focuses onto a mirror in the film box. The film remains stationary while the mirror spins at a rate of 100,000 revolutions per minute, deflecting the light images from the electronic shutter to the film.

The Ellis camera was built at Caltech during a program of basic studies in hydrodynamics under the direction of Milton S. Plesset, professor of applied mechanics. The program was supported by the Office of Naval Research. The camera is currently being used in studies on the mechanical and chemical aspects of cavitation, under a National Science Foundation grant.

In the future, Dr. Ellis hopes to continue with more advanced research on high speed impact, high frequency fatigue, and wave propagation in metals with the ultrafast camera. This extended research should prove valuable, not only in cavitation, but also in the fields of missile mechanics and space exploration.

Mathematical analyses are made to determine why bubbles damage underwater machinery.