55th Street

16 mm Demonstration

Set-up

WALLER GUNNERY TRAINER

(Covered by U. S. and foreign patents)

THE VITARAMA CORPORATION

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3/19/41

The Waller Gunnery Trainer

Before proceeding to a detailed description of this apparatus the following brief history of its invention and development is presented:

In August 1938 Mr. Fred Waller was called into consultation by Mr. Ralph Walker of the firm of Voorhees, Walker, Foley and Smith, Architects, of New York, in connection with an idea of Mr. Walker's for the projection of motion pictures on a curved screen of large area for use in an exhibit at the New York World's Fair.

Mr. Waller has had many years experience in both the technical and production fields of the motion picture industry. He has made many important mechanical and optical inventions regularly used in the making of modern movies, and is particularly familiar with the technical side of the making of "trick" pictures, i.e. pictures which produce effects otherwise unobtainable or too expensive for straight photography.

The result of the conferences between these two men was the invention and joint patenting of the "Spherical Screen Process" used in the Waller Gunnery Trainer. Outgrowths of this basic invention, but not incorporating all of its principles, were the motion pictures in the Perisphere, and the American Museum of Natural History's "Time and Space" show, both at the New York World's Fair, and produced by Mr. Waller. Mr. Waller also edited the Eastman Kodak "Cavalcade of Color" both years.

At the same time Mr. Waller proceeded with the design and construction of the first working model of the spherical screen process, which was set up in New York. From this first model much experience was gained and means for perfecting it developed.

In order to provide for financing further development the present Vitarama Corporation was formed in New York in November 1938 consisting of the following:

Voorhees, Walker, Foley & Smith
Mr. Laurance Rockefeller
Mr. Fred Waller
Mr. Leonard Outhwaite

Mr. Waller then set about the construction of the present working model and the production of a comprehensive sample film which would illustrate the dramatic and entertainment possibilities of the process. This work was completed and installed in its present location at 125 West 55th Street, New York, in January 1940.

In June 1940 Mr. H. Martyn Baker, an old personal friend of Mr. Waller's, entered the picture. Mr. Baker knew of the spherical screen process and had helped in the making of some of the film. He is a graduate of the Naval Academy, class of 1923. Realizing the need for training gunners to hit fast moving targets by personal judgment, he recognized the possibilities offered by the spherical screen process.

After several conferences with Mr. Waller, and after deciding on the means by which the desired results might be achieved, Mr. Baker went to Washington in late June 1940 to see if the armed services of the United States would be interested in such a gunnery training device. He found considerable interest in his verbal description, particularly on the part of Major L. J. Carr Army Air Corps. Shortly after, Major Carr came to New York and viewed the "dramatic" film. He was sufficiently impressed by this demonstration to obtain authorization for The Vitarama Corporation to make a special picture with the Army Air Corps which would illustrate better the possibilities of the process in training aircraft and anti-aircraft gunners. This film was made at Mitchell Field during August and September 1940 with the personal assistance of Captain William Ball of the 9th Bombardment Group.

Upon completion of this film in August 1940 it was viewed by a Board of Officers of the Army Air Corps and by officers of the Navy and the Marine Corps. At that time only the picture was available for inspection. The dummy

gun and its related recording mechanism had been planned but not built. Lieutenant Colonel C. W. LeGette, Marine Corps, was greatly interested in the whole project and at his instance construction of a working model of the gun was undertaken.

Mr. Robert Dresser, head of the Audiotone Oscillator Company of Bridgeport, Connecticut, was called in to design and build the electrical end of the apparatus. Mr. Dresser is an exceedingly capable electrical engineer, particularly in the field of electronics, with many important inventions and developments to his credit.

Mr. Waller, Mr. Baker and Mr. Dresser built parts of the apparatus in their respective shops which were then assembled with the projector and screen in New York and placed in working order in early February, 1941. The entire apparatus has been inspected, at the time of writing, by Colonel LeGette and Captain Davis of the Marine Corps, and by Colonel Patrick, Major Lee, Major Wolfe and Major Martha of the Army Air Corps and Commander Louis DeFlorez of the Navy.

Basic Principles of the Waller Gunnery Trainer

The fundamental theory of the Spherical Screen Process is that, for the average individual, the perception of distance and perspective beyond about twenty feet is not due to the interpupillary distance of the eyes, but is due to peripheral vision, (what the eye sees outside of its central area of sharp focus) to relative movement perspective, and to color perspective. The Spherical Screen Process simulates what the eye normally perceives by filling a screen, which is approximately a portion of the inside of a sphere, with a motion picture. The angular dimensions of the screen are nearly those encompassed by the normal human eye, and the angular relationships of any object, fixed or moving, on the screen are the same as those seen by the eye in actuality.

Thus, to an observer located near the optical center of the screen,

the requirements of peripheral vision and movement perspective are satisfied. By the use of color film the proper color perspective is introduced. The observer finds himself surrounded by a normal visual effect, in which objects move in a normal manner, and which gives the normal effect of distance and perspective.

To this visual picture is added sound which appears to move as the source of the sound moves on the screen. With the two most important senses of perception thus satisfied in a normal manner it is possible to recreate any desired environment. The success of the spherical screen process in accomplishing this is evident to any one who has witnessed a demonstration.

For gunnery training purposes a picture of the desired target, say an airplane, is produced. To the observer this target does not remain more or less fixed upon a single rectangular screen before him, but moves within his field of vision in an entirely normal manner, thus enabling him to exercise his judgement of distance and motion as though in the field.

The observer is then placed behind a dummy gun, located near the optical center of the screen, with which he attempts to hit the target. By means of suitable apparatus which will be described, two things happen when the trigger of the gun is pulled. First; if the gun is aimed so that a hit would be made, this fact is instantly announced audibly. This enables the person being trained to make an immediate mental note of the judgment and actions which led to success. Second; whether or not a hit has been recorded, the mechanism operates to project on the screen a spot of light showing where the imaginary burst of fire struck in the plane of the target. This spot does not appear the instant the trigger is pulled, but is delayed for a time interval representing the time of flight of the shot from the gun to the target at whatever range it may be. The person being trained is thus enabled to see his hit if made, or if not, to see the direction and amount of his error in aim and so correct himself in successive attempts.

In this way the Waller Gunnery Trainer not only reproduces for the observer any desired environment and target but also correctly simulates conditions of firing in a way that otherwise could only be found in actual combat. Since anything can be produced on the screen that can be photographed, and since operation of the Trainer is independent of weather, time, and the availability of actual equipment, it offers a valuable means of training in preparation for and supplementing actual firing.

The Existing Working Model of the Waller Gunnery Trainer

Since the existing working model is what is available for inspection and trial, it must be described in some detail. In fundamental principles it differs in no way from the full size apparatus which would be furnished to the service, and it fully demonstrates what can be accomplished. In mechanical detail and in appearance it differs considerably. This was made necessary by considerations of economy, and the availability of space in existing equipment. Also, it was originally designed to present a picture to a theater audience and not to a comparatively small number of observers being trained in gunnery.

The spherical screen is of 10 foot radius, with a short conical section around its perimeter. It covers 165° in the horizontal and 75° in the vertical planes. It is of a patented strip construction designed to reflect light uniformly to a large audience and not to reflect light from one section to another of the screen itself. This rather complicated construction would not be necessary for gunnery training purposes, and a simplified form which will be described later would be furnished to the service.

The multiple camera with which the pictures were taken consists of eleven inexpensive 16 mm amateur motion picture cameras so arranged in a frame as to cover the desired field. The individual spring motors have been removed and all are driven in synchronism by one 12 volt constant speed electric motor.

The multiple projector unit similarly consists of eleven 16 mm projectors so arranged in a frame that each covers the same area as its corresponding camera. Masks are installed in the aperture plates so that the picture thrown by each projector joins that of the next so as to form a complete mosaic over the surface of the screen. Each projector is driven by its own motor but all are connected and held in synchronism by an arrangement of chains and sprockets. The entire battery of projectors is also mechanically connected to a constant speed motor which keeps it running at the standard speed of sixteen frames of film per second. The projectors are contained in a housing to reduce noise, the delivery and take up reels being located on the outside of this housing.

It was necessary to use eleven cameras and projectors because of the availability of suitable lenses, and also to get sufficient screen illumination through the very small area of a 16 mm frame. It should be noted that in the full size apparatus, using standard professional 35 mm equipment, the number will be reduced to five, greatly simplifying the installation.

This 16 mm amateur equipment leaves much to be desired in mechanical accuracy and in performance, and is responsible for the somewhat uneven screen illumination and the prominence of the lines dividing the parts of the mosaic which mar the demonstration pictures. In considering the results to be obtained from the full size equipment it is only necessary to compare the unsatisfactory performance of the small equipment with the results familiar to every movie goer, in even the least pretentious theater.

The sound which accompanies the picture was re-recorded onto discs with three separate spirals on each disc. Playing time is therefore limited to about three minutes and necessitates stopping to change records. Since the re-recording was manually controlled it is not always true to the picture. It does, however, demonstrate the remarkable effect of realism to be obtained by the use of stereophonic sound in connection with the spherical screen. Sound for

As with the spherical screen picture apparatus, the model dummy gun and its attendant recording mechanism function for the most part exactly as the full size apparatus would; they present a crude external appearance for purposes of economy and were designed and built to fit the small space available.

The gun itself (four in the service trainer) is located near the optical center of the screen and mounted so that its motion in elevation and train is transmitted to the recording unit by flexible steel cables. Within the gun barrel is the optical system which projects the spot of light on the screen which shows where the "burst" landed, as mentioned above. Two solenoid operated brakes "lock" the gun in position the instant the trigger is pulled and remain locked until the spot of light (the burst) appears on the screen. The gun then unlocks and is ready for the next shot.

In this respect the model differs from the service apparatus. In the latter, on pulling the trigger, the "burst" light projector only would be locked, permitting the operator to continue following the target with his sights. The only restriction, and departure from actual firing conditions, is that a second shot cannot be fired until the first has appeared on the screen. In other words the gun will simulate the firing of successive short bursts but not continuous machine gun fire. However, if desired, the solenoid brakes may be disconnected, allowing continuous following and firing at the target. In this case, hits will be recorded, but the "burst" images will not appear.

The recording unit fulfills two functions: one, to record hits as made; and, two, to introduce the time delay in the appearance of the spot of light which corresponds to the actual time of flight of the shot to the plane of the target. These functions will be described in turn.

The recording unit consists first of an intermittent film moving mechanism similar to that in a motion picture projector with delivery and takeup reels.

This is driven synchronously with the picture projector so that for each frame of picture shown on the screen a corresponding frame of black 35 mm film is presented in the two apertures of the recorder. The lower and larger aperture is where the record of hits is made. Traversing the whole area of this aperture and driven by the flexible cables connecting it with the gun, is a light source and optical system terminating in a small brightly illuminated opening of cross shape. When this coincides with a similar cross punched in the film the light shines through on a photo cell. The electrical response of the photo cell is then amplified to actuate the desired signal indicating a hit - in the model by ringing a bell. The size of the cross of the light source is adjustable, providing a means of increasing or decreasing the "dispersion" of the imaginary "burst". In other words, if desired, the beginner may be permitted to record hits with a less accurate aim, or a larger imaginary pattern of shots.

The upper and smaller aperture, a narrow slot across the record film, is where the time delay of the "burst" is introduced. A light source illuminates this slot. The instant the trigger of the gun is pulled a metal plate with a small square hole in it starts across the aperture at a constant speed, traveling the full distance in about one second. A similar square hole is punched in the film at a variable distance in from the edge, corresponding to the time delay desired. When the hole in the moving scanning plate uncovers the hole in the film, light shines through on a second photo cell which in turn through amplification causes the "burst" spot to be projected on the screen from its optical system in the gun barrel. At the termination of the cycle all electrical circuits are cleaned out and the gun and recorder ready for the next shot.

We must now consider the accuracy of the entire gun and recording apparatus and the methods by which the point of aim of the gun and the punching of the cross hole in the record film is determined.

Since the entire travel of the gun in elevation and train is reduced to cover an aperture which measures about 1" x 3/4" it is evident that a high degree of mechanical precision is required. This has been successfully achieved even in the present rather crude apparatus. There is, therefore, no doubt but that a materially higher degree of accuracy will be achieved in the service apparatus where suitable metal parts will be substituted for the plywood construction of the model. In its present form a hit will be recorded corresponding to a dispersion pattern of about 10 mils of actual machine gun fire. This can be increased at will as explained above.

In determining the proper point of aim we have two sets of known factors to work with. First, the ballistic tables for any given type of weapon, which give time of flight and trajectory for all ranges and angles of fire. Second, we have on the picture film a complete record for every 1/16th second of time (each frame of film) of the course and distance of the target. In the model, distance has been computed from known speeds and angular measurements of the targets. In service it would be determined by photo triangulation.

With these two known sets of factors we are in a position to work backward, so to speak. At every 1/16th of a second we know the exact position of the target on the screen, and its range, therefore we know the time of flight of the shot to make a hit. Let us assume that this time of flight for this particular target position is 3/4 second or twelve frames of film. We assume a hit to have occurred. Then in imagination we back the shot into the gun for twelve frames, and correspondingly we back the target on its course for twelve frames. The target is then in the only possible position for the assumed hit to have occurred. A punch is substituted for the cross light source. The gun is aimed at the target on the screen frame by frame in stop motion, each frame of the record film is punched. In running, however, the punched frames of the record film are advanced ahead of the picture film by the number of frames cor-

responding to the changing time of flight. Therefore, if the gun is aimed at the place of the hit, that fact is recorded although the picture shows the target back on its course by the time of flight of the shot. In this way an absolutely accurate method of determining the correct point of aim or "lead" is available without recourse to any mathematical calculations whatever. Since this has been done for each frame of picture film, the person being trained may pull the trigger at any time and have his hit recorded if he makes it.

The time delay square hole in the record film, referred to above, is then added to each frame by simply laying off its distance in from the edge of the film to correspond to the time of flight for that frame already found.

The accuracy of this entire operation is limited only by the fact that the motion picture actually shows a succession of still pictures 1/16 second apart, instead of a continuous motion. Since the eye accepts this succession of still pictures for continuous motion, the inaccuracy introduced is beyond human perception.

The only other apparatus used is for editing, rewinding, etc., and while essential to the production and operation of the trainer, does not concern us here.

The Service Apparatus of the Waller Gunnery Trainer

It must again be emphasized that in the full size service form of the Waller Gunnery Trainer all physical, optical and electrical principles will be identical with those of the existing working model. To a large extent this is also true of the mechanical details. Where differences occur they are in the interests of simplicity, accuracy and reliability. Many of these differences have been noted in the description of the working model. At this time, however, a more detailed description of the service apparatus is in order.

To a large extent advantage will be taken of existing professional 35mm motion picture equipment which has long ago been brought to a high degree of perfection. Much of this equipment is readily available on the market and can easily be adapted to use in the spherical screen process. With the larger area of professional film the number of cameras and projectors will be reduced from eleven to five. This not only greatly simplifies the apparatus but reduces the time required for rewinding and reloading to a small and probably desirable break in the training periods.

The screen will be increased in size over that of the model. Our recommendation is that it be of 20 foot radius. This size will give satisfactory illumination and provide room for the installation of four guns. In addition, since binocular vision practically ceases at this distance, there will be no mental confusion for the observer due to his binocular vision telling him that screen surface on which he sees the picture is at a short distance while the other qualities of his vision tell him that the object he is watching is at a long distance. This size is of course not a hard and fast rule, and varying it somewhat would not affect the rest of the apparatus except to reduce the number of guns if appreciably reduced.

The construction of the screen will be greatly simplified over that of the model. Since it is desired to have most of the reflection back toward the immediate vicinity of the projector the surface will be smooth and coated with a paint having a nearly specular reflecting quality. The type of coating has already been determined by extensive tests on many kinds of reflecting surfaces. The screen will consist of light plywood, moulded in bonding to the radius of the sphere and cut in suitable sections to facilitate handling and erection. This will be supported by a light steel frame.

The projector unit will consist of five standard projectors, of a type already government approved. These will be of the silent type, the area of the usual sound track being used for picture. Masks to form the mosaic will be

placed in the aperture plates at the focal plane of the film. Since these aperture plates are fixed and since the pull down mechanism is accurate in operation, placing each frame of film at exactly the same position, it will be possible to reduce the visible demarcations between the five fields to the point where they are hardly noticeable and not disturbing.

The five projectors will be mechanically held in synchronism. Since each is driven by its own constant speed motor the synchronizing mechanism will carry only a small load when starting and practically none when they are up to speed. The gun recorders will also be mechanically synchronized with the projectors. This is considered preferable to an electrical interlock of the Selsyn type both from the points of economy and reliability.

The five projectors will be rigidly mounted with respect to each other and the screen so that the picture areas covered will remain constant.

The projectors will be illuminated by incandescent lamps of 1500 watts, eliminating the need for constant attention required by arcs. The life of such standard projection lamps is about 25 hours. These lamps are blower cooled and provision will be made for carrying off the heat.

The entire projector unit should be enclosed in a suitable housing to suppress noise and to enable the projection crew to work efficiently.

The guns - four are considered practical for a 20 foot radius screen - will be patterned to resemble actual pieces in appearance and feel. If desired the immediate surroundings of each gun can also be made to resemble service conditions, such as placing in a turret, requiring a prone position, etc. The functioning of each gun will be similar to that of the model except, as previously mentioned, that the gun will be always free to move, the light projector only being locked in position on pulling the trigger until the "burst" has appeared on the screen. Different colors will distinguish the "bursts" of the different guns.

The recording mechanisms, one for each gun, will function in the same way as that of the model. A double frame of record film will be used for the "aim" area thus at once halving any errors of the model. Construction will of course be in accordance with the standards of accuracy of professional motion picture practice. The record film itself will be a photographic print instead of having actual perforations, permitting easy duplication from a master, and avoiding any weakening of the film. Special 4000 foot reels will be provided to take the double length of record film needed with a 2000 foot picture.

The electrical circuits and amplifiers will be similar to those of the model.

The sound equipment furnished would depend to a large extent on the particular type of training to be given, i.e., on what degree of realism it is desired to incorporate. For certain purposes no sound at all might be needed.

The simplest and least expensive form of sound equipment would consist of a turntable carrying 16" disc records and turning at 33-1/3 rpm. This provides a playing time of about 16 minutes and by the use of two pick-ups could be made to furnish sound for the full 32 minutes of a 2000 foot film. Such sound cannot be accurately synchronized and would be useful only to reproduce a continuous noise such as the sound of an airplane motor. An amplifier and speaker, or possibly head sets for the gun operators would be needed. A better and somewhat more expensive way of achieving the same result would be by the use of a film phonograph carrying a continuous loop of sound track film. This method would have the advantage of requiring practically no attention by the operating crew.

For sound which is synchronized with the action of the picture the use

of a film phonograph with a sound track film is necessary. The film might carry but a single track if only volume of sound were required from a single amplifying and speaker system. The most elaborate and realistic method would be the use of three sound tracks on a single film with three amplifiers and speakers thus producing the illusion of the sound moving as its source moves in the picture. The value of the various methods should be carefully considered with their cost for the purpose intended.

The above description covers the mechanism of the Waller Gunnery Trainer as it would be furnished to the service. A suitable building for housing the apparatus would be required and could either be a separate structure or incorporated in a larger building. Sound proofing would be desirable. Special fire precautions are not needed as the color film used is of the safety type. If desired The Vitarama Corporation would be pleased to submit suggestions or plans for such a building. The Vitarama Corporation would furnish and supervise installation of the equipment and instruct the personnel in its operation.

As described above the Waller Gunnery Trainer could be operated by a crew of two or three enlisted men of non-commissioned grade. Actual operation and routine servicing is such as to be mastered by a man of average intelligence in a few days. Between five and ten minutes would be required between each running for reloading. Rewinding of one set of films can be done while a second set is running. A single running of a 2000 foot picture film at sixteen frames per second would require about 32 minutes.

In addition to the training units as supplied to the service certain equipment is required in order to photograph, edit, and duplicate the picture film; and to prepare the master record films and duplicate them. This equipment includes a five camera picture photographing unit, photo triangulating cameras, an editing and recording machine, and certain smaller