few woods, so practically the whole area is accessible to easy stereoscopic observations.

The maximum difference in elevation, I think, is within ten feet, and there are two-foot contours throughout the area. One can contour the roads, if desired, within a few inches.

The marks themselves have been determined by triangulation within one decimeter and have levels so that the position is correct without any traverse adjustment within that decimeter.

The data for the survey have not yet been received from the field. It will probably be two or three months before they are available, but if any of you would like to use them, I am sure the Coast and Geodetic Survey would be glad to make them available.

PRESIDENT MASSIE: Thank you very much, Commander Reading. I have a hunch that you will be called upon for some of that material.

Our next speaker, Mr. Podeyn, obtained his education at Lehigh and New York Universities. For the past five years of his association with Fairchild Camera and Instrument Corporation he has specialized in aerial photographic and photogrammetric equipment. He has been working especially with the phases of the work connected with radar.

Mr. Podeyn is the author of several articles dealing with radar charting. At present he is Manager of the Commercial Aviation Equipment Division of Fairchild Camera and Instrument Corporation. His paper, "Radar Charting, a New Application of Photogrammetry," deals with one of the newest and most exciting developments in mapping of the recent years. Mr. Podeyn.

MR. PODEYN: During the war, radar was born and grew to be a lusty youngster before many of us had heard of it. Such security was essential, of course but it has resulted in our having only begun to make non-military use of this electronic tool very recently.

There were only vague conjectures as to the peacetime usefulness of radar photography because the first job was to produce training photos. Bombardiers and operators first grew to know radar from photos made with cameras stuck on "stove-pipes" which were mounted on the oscilloscopes. Many ingenious methods were used to keep records of the images presented on the radar scope. Most of these were devised by field personnel who used what was at hand to solve the problem. As a preliminary effort to supply a complete recording system, we worked with radiation laboratory in production engineering and produced a quantity of what was then known as the Bolex Coffin. This unit was suggested by personnel of the 8th Air Force and was a fancy modification of a standard movie camera which was mounted in one end of a light tight box. A slave scope, clock and other data was grouped at the opposite end of the box. All of this information was automatically recorded.

Although the coffin was capable of producing very good radar photographs, it was large, awkward to use and in general just a very clever field unit. To obtain improved equipment, several independent efforts were being made to design the ideal radar camera. Security prevented complete liaison and kept these efforts individual for a time but the prototype of present Fairchild radar cameras was examined and interested Army and Navy personnel.

The Army, Navy and radiation laboratory joined together to make a "crash" project of the production of this camera which has been the standard radar camera with the Army and Navy since that time. Since the end of the war, this camera system has been refined and adapted for many radar, oscilloscope, and instrument recording jobs and also for conventional aerial photographic uses on magnetometer surveys.

Photogrammetric possibilities of radar were explored a little during the war. Of course radar navigation charts were needed as soon as radar was put in use. Radar images were photographed during the war in order to record the bombing runs made over targets and were also used on the runs to and from target areas to gather reconnaissance information in much the same way that aerial photographs were used. During this time, considerable work was done in preparing radar charts to be used by bombing squadrons in order to locate their targets in overcast weather. A few early charts were based on photography but many of these charts were artists' conceptions of what the radar picture would look like. These helped but were not good enough. Dr. Paul Rosenberg of radiation laboratory made many radar photographs over Europe studying this problem and was asked to prepare radar charts of the Tokyo area many, many months before our planes flew over this area. In order to prepare these charts, special reflection models were made and placed in tanks of water and then the models were scanned in radar fashion by a supersonic device which placed an image on a radar type oscilloscope. These images were the closest to the actual images the radar operator would see as he flew over the target. Thousands of photographs were used during the preparation of these charts and also in the preparation of a radar mosaic of the entire Holland, Belgium, France invasion area. These charts were remarkably effective considering the comparatively low resolving power of the radars then used in aircraft and also considering the great difficulties under which these charts were prepared.

Since that time, improved radar equipment and photographic techniques together with the increased knowledge gained through postwar studies of the problem by the Army, the Navy and the CAA have brought airborne radar charting very close to the point where it could be used by commercial airlines for radar navigation from point to point. In December 1946 the airway from Chicago to New York was radar photographed from the Civil Aeronautics Administration's B-25 in which an A.P.S. 10 radar was installed. This was in Technical Development Report #66 by R. C. Borden and E. C. Williams. When the negatives of this series of radar photographs were enlarged to the same scale as the aeronautical navigation chart for this route, it was possible to lay these photographs out in mosaic form rather easily when there were sharp differences in elevation such as you find over the mountains of Pennsylvania, or shorelines of lakes and rivers. Over level areas without large bodies of water, it was a different matter. The reflections from these areas were too even. Some work is now being done to develop a method of presenting information over these flat areas, which will assist the radar navigator in picking up the salient points presented on the radar scope. When this is completed, properly trained air navigators can navigate with assurance in any weather.

However, satisfactory radar charts for marine navigation are usable today and the techniques for their preparation are comparatively simple. So simple, in fact, that this technique may be used to plot new buoy locations in rivers where the channels change frequently. Radar type charts will be used instead of the present work notes issued when buoy changes were made.

As a general side note, a form of charting is being seriously considered by ship owners as a means of protection in case of mishap. The standard radar camera mounted over the scope with the same periscope and beam splitter arrangement used in charting permits record photographs to be made at regular intervals (Fig. 1). These show the time, such handwritten data as the name of the vessel and the name of the harbor being entered, and from this series of photographs, it will be possible to plot the speed and courses of vessels which may be involved in an accident while running under radar guidance. Such a record is actually a series of charts with vessel position, buoys and other vital information plotted with range rings registered to give an easy check on the scale of radar chart.

Another use of radar photography is in the recordings of landings of aircraft under ground control approach guidance. Other interesting uses of radar photography are still classified but will some day be available to civilians.

Although many of you are already well acquainted with radar, it will help

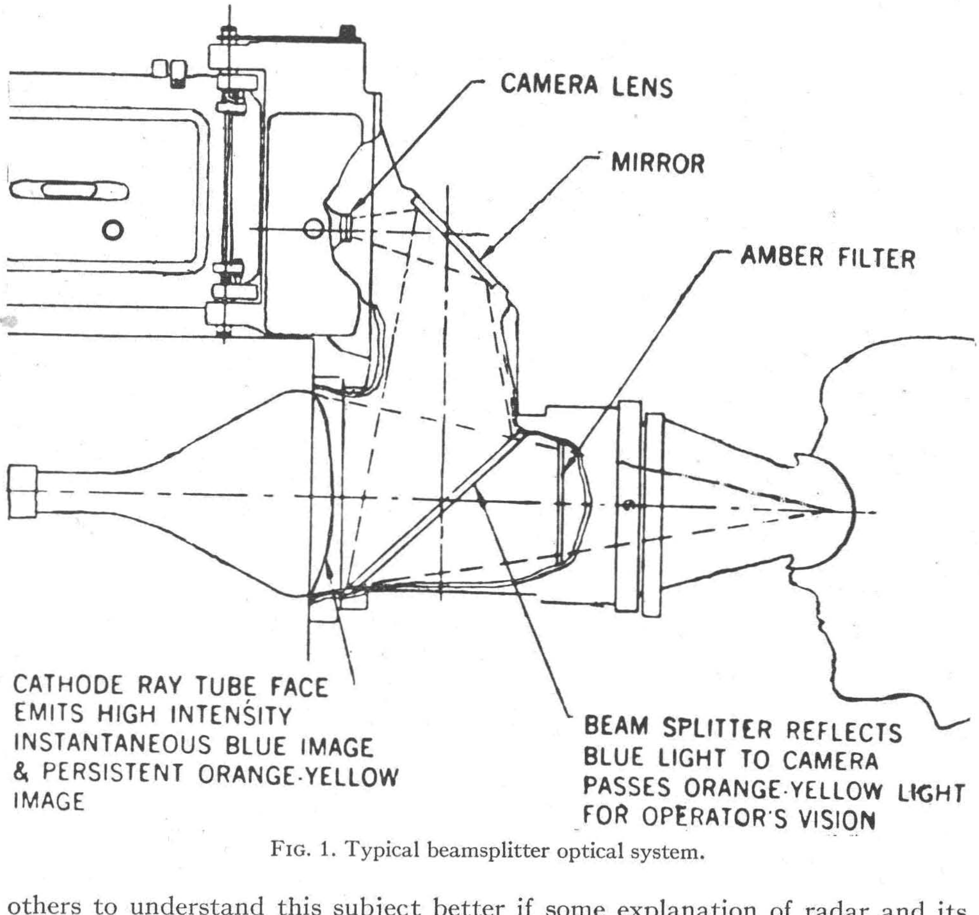

FIG. 1. Typical beamsplitter optical system.

others to understand this subject better if some explanation of radar and its operation is given at this time. That is, radar operation as it affects the map maker.

Radar is something like a searchlight beam which is swung around the horizon and in which radio energy is substituted for visible light. In the case of marine radar charting, such as is being performed on the Ohio River, the radar antenna or scanner is mounted approximately forty feet above the waterline either on the ship's mast or some other suitable point, such as the roof of the pilot house. This scanner rotates through 360° every five to eight seconds, depending on the scanning rate of the particular radar and in so doing sends out high frequency pulses which, since they travel so rapidly, are received back at the same antenna and are converted into a picture along a radial line on the face of the oscilloscope. A nearly vertical object, or one made of steel or stone, produces a much stronger reflection than one received from vegetation or from a nearly horizontal surface. The relative positions of strong and weak reflections are placed on the scope electronically in proportion to the length of time it took for them to return from the object to the radar antenna. As the sweep moves across a radial line on the oscilloscope, the image is thus made bright or dim, depending on the strength of the signal received. Since many of these lines are being traced in 360° of rotation, the pattern appears to be continuous and shows the presentation around a horizon limited by line of sight in which the radar antenna is the center. The photographs are, therefore, somewhat similar to an aerial photograph whose optical axis is coincident with the axis of rotation of the radar antenna (Fig. 2).

FIG. 2. Ore carrier at junction of West Neebish and Middle Neebish Channels near St. Marie Locks. Notice how clearly the channel buoys are indicated.

The image is traced by a beam of electrons which is guided along a radial path on the face of the oscilloscope. This beam appears on the scope face as a point and it is this point or trace which is used in the special photographic equipment designed to record these images. The trace is a blue of almost ultra-violet quality, and as it bombards the coatings on the inside of the oscilloscope, these fluorescent coatings are triggered and continue to glow for several seconds. The image which remains is the residual or persistent image, and it is this image which is used by the navigator. However, because there is diffusion in this persistent image, it is very bad for the map maker. It is better to have a sharp image from which to make radar navigation charts.

Therefore, by color selection (we call it beam splitting, see Fig. 1) we let the spot trace the image on the film, at the same time it works on the tube. The total exposure to record a radar image is, therefore, the same as that required for a complete scan of the radar antenna. The shutter is electrically operated and is timed by the radar so it is always synchronized. By means of a control box with a counting down relay, selections can be made among the scans, and selections of the interval between pictures is based on the same factors which affect the interval between aerial photographs. So much for the general introduction to this subject.

The reason for using radar photographs to prepare charts instead of aerial photographs is easy to understand when we think of making radar charts specifically for radar navigation. The radar image is similar to the actual terrain if we have sharp differences such as steep shorelines or in the case of aerial radar charts, shorelines and ridges. (See Fig. 3.) However, the images are not precisely the same due to differences in reflection and radar shadows cast by high terrain in the foreground. And only from the radar itself can you tell how a particular area will appear on the radar scope.

This is easily demonstrated by studying the conventional charts of the Ohio River as compared to the radar charts now being prepared by the Corps of Engineers. In Figure 4 you will notice that the shoreline of the radar mosaic very closely follows the shoreline of the conventional river chart. However, the back reflections away from the shoreline are of perhaps the greatest value to the navigator in locating himself along the river. At no two points along the

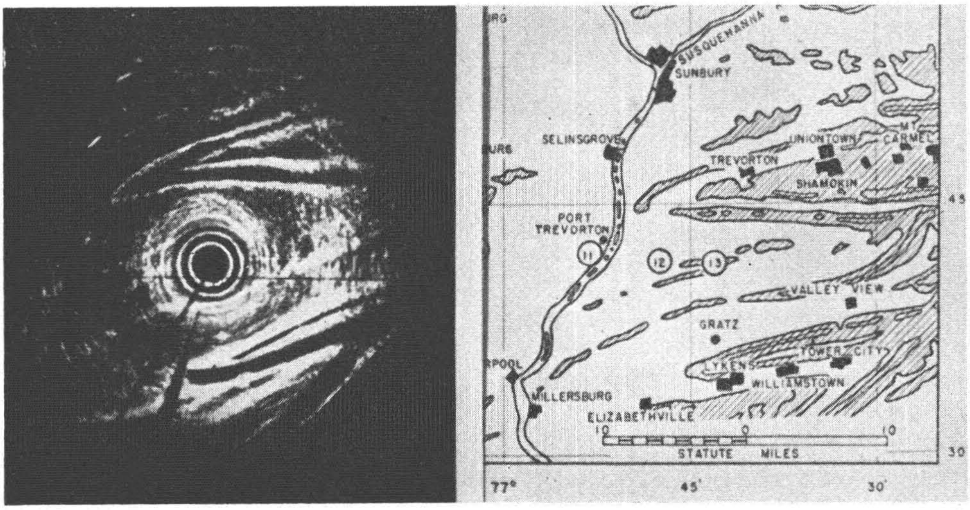

FIG. 3. Mountainous area near Sunbury, Pa. Shaded relief chart would be an improvement over contour chart shown.

river will these reflections be exactly the same and it is very important for the navigator to place himself accurately when he is running completely blind except for the picture he sees on the scope.

In preparing these charts, Colonel Talley's group has developed a straightforward system which uses a conventional flat bottom, diesel powered river boat which provides living quarters, dark room facilities, and work areas for planning the survey as it progresses. The survey party itself consists of three men and there are eight men and a pilot required to operate the boat. The survey party itself consists of the engineer in charge who is the mapping specialist; the radar engineer who operates the radar and keeps the equipment in adjustment and repair; the photographer who actually makes the photographs and handles all film processing on board.

The actual survey is made as the vessel travels at a steady seven miles per hour along the sailing line which appears on the conventional river chart. This produces the optimum image or that one which is seen on a vessel which is following the proper sailing line. The images even close to the bank will be quite similar but the back reflections will vary a little depending on the height of the bank.

In general, the photographs are made one-half mile apart along the river. The photographer watches the scope constantly and when a point has been reached where it had been previously planned to make a photograph, the photographer throws a switch which allows the image to appear on the radar scope and which at the same time starts the camera.

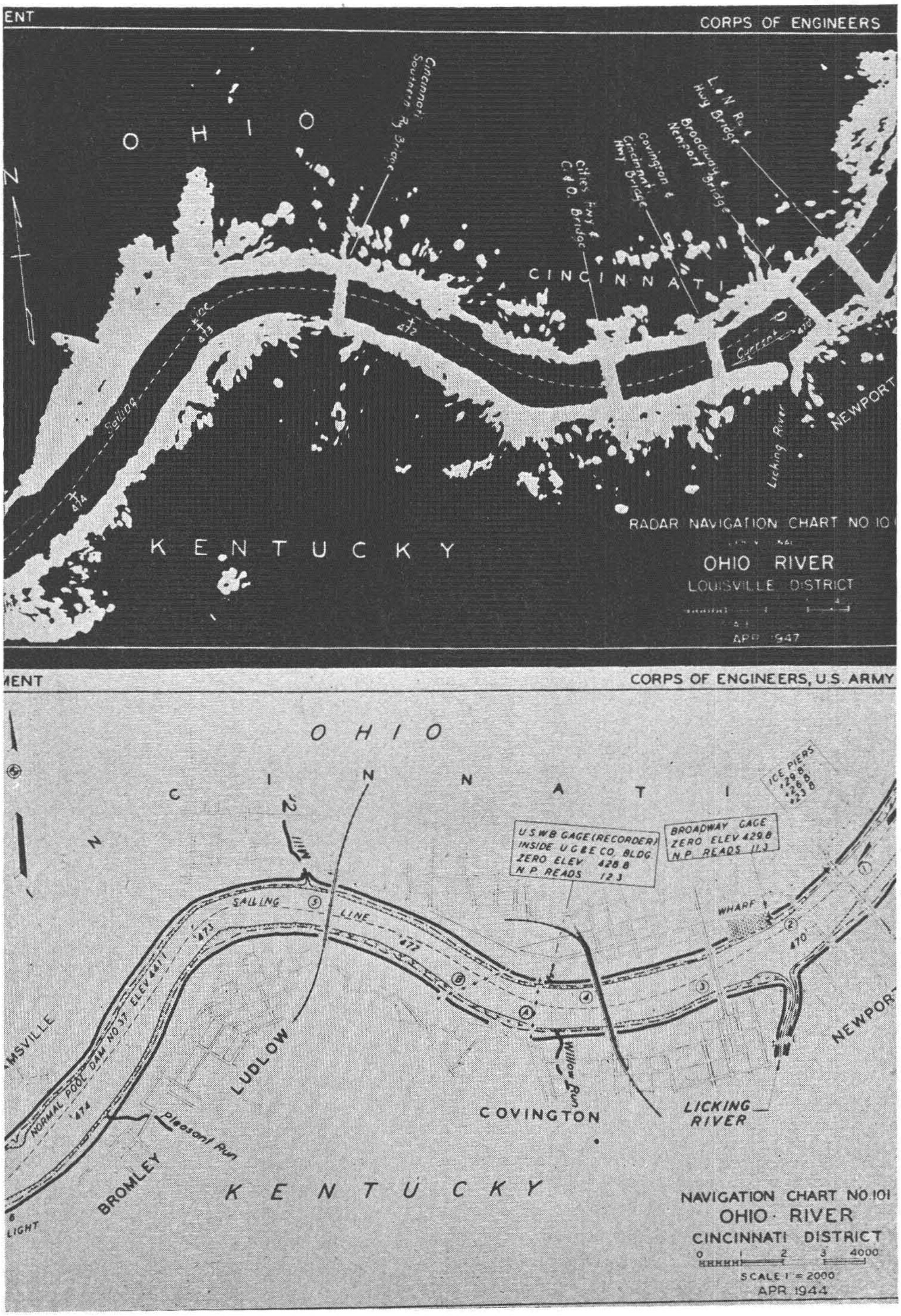

FIG. 4. Comparison—Radar navigation chart and conventional chart. Future charts should combine both radar and conventional charts.

On the Ohio River, the picture is permitted to appear on the scope only when photographs are being made. This is to reduce the effect of the residual or persistent image, which in this particular case, has a rather high percentage of blue and, therefore, records along with the instantaneous trace. To eliminate this effect, the scope image and the camera are started simultaneously. A series of consecutive pictures are made at each photographic point, and after five pictures have been taken, the scope and the camera are switched off.

It is good to point out here that, based on his experience gained during experimental surveys prior to the time that this major survey was started, the photographer takes the pictures between the half-mile point opposite creeks, tree-

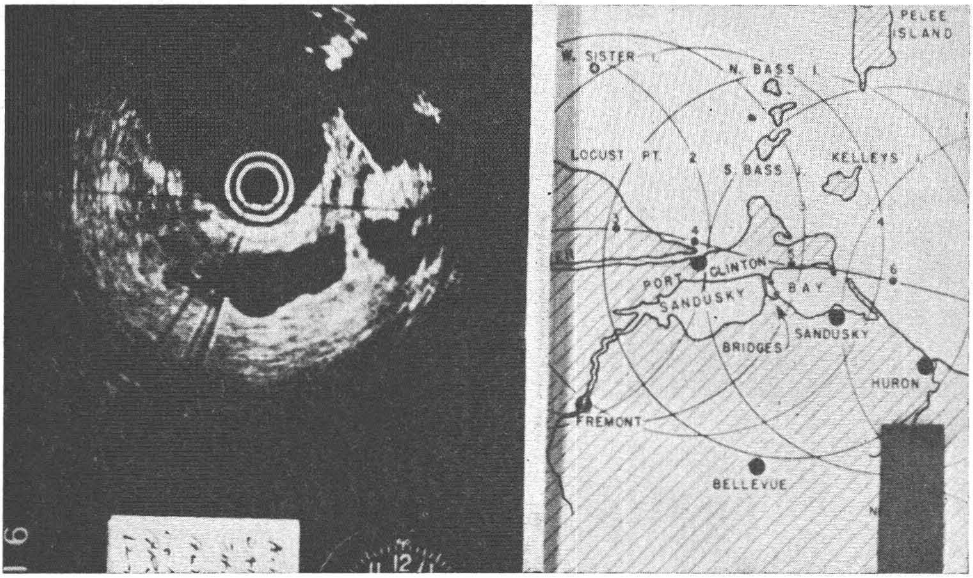

FIG. 5. Aerial radar photograph of Sandusky Harbor. Circle No. 4 on map is area covered by this photograph.

lines, bluffs, bridges or other prominent reflection points. These give shadows usable as check points when making the mosaic and constitute a sort of secondary control for the survey.

So far, in 200 miles of formal charting, the match between the radar charts and the conventional river charts has been perfect. And as a matter of fact, the shoreline as presented by the radar is now considered to be slightly more accurate than the shoreline as presented on the original survey of 1913. This is due to minor bank changes since 1913 and is for all practical purposes of no great importance.

On the river, minor bank changes have no effect on piloting because the pilot uses "eye-estimates" and landmarks in placing his boat on the sailing line. River pilots are remarkable in their ability to navigate tows 1200 feet long through a winding river valley with relatively few aids to navigation and without the aid of any compass or other navigational instrument. For such men radar charts are very easy to use. Operating this way the boat travels approximately 35 miles a day during an eight hour day. Time is allowed in this estimate for passing through locks and other routine navigational delays.

At the end of each day's run, the film is processed in an automatic developing unit similar to those used for aerial photographic film. In this case, however, very little film must be processed at a time since an entire day's run uses only about thirty feet of a 100-ft. roll of 35 mm. film. After processing and drying on a rack designed for handling this film, it is checked by projecting the 35 mm. negative onto conventional charts to check the radar presentation against the actual chart of the river. In this way, backtracking is minimized if any of the work should have to be rephotographed. No new photography has been needed so far.

After the film has been processed and checked, it is sent to the main office in Louisville in order that the map making can proceed parallel to the boat's charting efforts. In this case, coordination is maintained by means of radio between the main office and the vesssel. Another help in correlating the photographs is the data recording feature of the camera. Since the camera records the number of each photograph on the negative and these numbers are also recorded on the key charts which are sent along with the negatives, the laying down of mosaics in the Louisville office is greatly simplified. Enlargements are made to the same scale as the conventional river chart. The work is greatly speeded up by checking radar mosaics against aerial mosaics of the same area. However, in an area where such help is not available the work can still be done at a somewhat slower speed.

The radar image varies slightly from day to day in its scale. However, once set for a particular day, and these adjustments are minor ones involving only external controls, the radar maintains this setting all day so that enlargements made from a particular day's run are all so close to the same scale that only minute changes must be made in the enlarger's setting when positive prints are being made. All photographs are made with the F.T.C. circuits turned on. This circuit cuts off all signals below a certain strength and in this way produces a much better image for charting than would otherwise be produced since clutter is eliminated and only the salient features stand out on the scope. The amount of F.T.C. used can be varied and in this case the setting is such that no breaks appear in the shoreline at all.

A little data may be useful—the scope intensive setting is number four and the camera diaphragm is at F5.8. The film used is background X which is very good since it is a fine grain film of the ortho type.

At this point it is well to explain that the ortho type film has been found to be far more sensitive to oscilloscope images than the panchromatic film because the blue sensitivity is high. This has been learned during experiments made on laboratory oscilloscope recording cameras which must record images traced in fractions of micro-seconds. In spite of this very short exposure, the images can be satisfactorily recorded. The range used on the radar is one mile which means that the radius distance of the radar is equal to one mile.

When completed and ready for use by river pilots, these charts have black backgrounds with white areas corresponding to the radar images. Some work has already been done by the Louisville district engineers to determine whether fluorescent ink would be usable for presenting this radar image on the conventional chart. It was thought that by such a method a perfectly conventional river chart could be issued over which had been printed the radar image in fluorescent ink and this image would glow when activated by ultra-violet light. The system worked but the fluorescent inks do not have sufficient light to last during the expected lifetime of a chart. It was therefore suggested that fluorescent treated paper be used over which other printing could be added and in the case of river charts this will probably work very well. However, in the case of

U. S. Coast and Geodetic Survey charts which have characteristic shadings for various areas, this will probably not work at all. It is, therefore, suggested that the radar chart be added to the conventional Coast and Geodetic Survey chart in some shade of ink which will not disturb the color code already being used. One color which has already been suggested is the color brown—a dark brown to be spread over the radar shadow areas.

It has been recognized on the Ohio River and is being recognized elsewhere that it is advisable to use the same charts with which folks are familiar for the presentation of both the conventional chart information and the radar information. This simplifies the problem of issuing the chart and also of cataloging and filing them on board the vessel.

This brings up the question which was raised by one of the best cartographers in the country; how to convert the radar image into a polychonic image. It is really not of such enormous importance to convert this radar information into the same precise presentation which forms the basic chart. Radar presentations themselves will vary somewhat as the vessel approaches a shore and will, for that reason, vary slightly from the precise survey although the general outline will be the same.

Radar chart presentation is important and willl have to be provided very soon because radar equipment is going on board vessels at an ever increasing rate as ship owners and ship masters begin to realize the benefits they derive by continuing to operate regardless of visibility. It is estimated that a vessel equipped with radar can save the cost of the radar installation in one trip; if without the radar it would have had to wait outside the harbor entrance for approximately 24 hours because of fog.

Ray marks and radar reflectors, which correspond to lighthouses and similar conventional aids to navigation, must be added along with the radar images to these conventional charts. The Coast Guard, the U. S. Engineers, the Navy and others are doing considerable work in the perfecting of such aids to navigation.

It is quite likely that the U. S. Engineers will do all of the inland waterway radar charting themselves, and it is also quite likely that the U. S. Coast and Geodetic Survey will do the shoreline charting, but there are many harbors in the world which will require radar charts and where the countries governing those areas do not have the facilties for preparing such charts . . . .

So far we have discussed the preparation of charts for radar navigation. However, radar presents very interesting possibilities for the preparation of conventional river and other charts where shorelines are important. While it is perfectly true that aerial surveying can be used in the preparation of these charts, the interesting thing about radar photography is the fact that it is practically independent of the weather. Only dense snowstorms or unusually heavy rain affect radar images. It has also been found that tip and tilt errors found in aerial photographs have little effect within wide margins in radar photographs. This is because the scanning area of the radar equipment is sufficiently large to allow for roll and pitch of the vessel with almost no effect on the radar image accuracy itself.

There are several influences on the accuracy of the map which is plotted by radar. The linear accuracy of plotting within the middle 80% of the radius of the trace is within four tenths of 1% of the ordinary plotting accuracy obtained in the drafting room. That is, according to Commander Reading's table of accuracy prepared for the MANUAL OF PHOTOGRAMMETRY, which in turn was based on the standards for the U. S. Coast and Geodetic Surveys, the graphic tolerance for ordinary plotting accuracy is .016." The radar plots within .02". This is very encouraging to the photogrammetrists since radar is capable of being improved and, in fact, experimental models have been built which exceed this accuracy by a considerable margin. The angular or bearing accuracy is not quite as good because of lost motion in the mechanical linkages within the radar system itself so that bearings are accurate within plus or minus one degree. Here again, experimental models exceed this accuracy and on special order, commercial models could be made to exceed this performance. The narrower the beam width and the shorter the pulse length of a radar, the more accurate will be the presentation of the chart by the radar itself.

For a detailed specification of good radar equipment, it is suggested that the general form of the specification drawn up for the Lake Carriers' Association by Jansky and Bailey be followed in selecting a radar for charting purposes. All present commercial radars will follow this specification rather closely.

There is one note concerning the radar which should be made. Radar is a piece of electronic equipment which requires skilled maintenance in order to keep it in proper adjustment. It will be essential for the survey contractor to invest in the services of a better-than-average radar technician.

The camera which has been developed for radar photography is quite different from conventional cameras but has been used in the field over a period of years. One camera has already made more than 5,000,000 photographs and is still in constant use in the field, so it is apparent that the photographic equipment and the radar equipment are available. The next step is to refine the field and office techniques.

It is hoped that this thumbnail sketch of radar charting and some of its possibilities will sufficiently interest the mapping experts gathered here so that they will give some thought to the problems involved in radar charting and in this way advance this new photogrammetric technique to a point where it will be as well understood and as well documented as the present science of aerial photogrammetry now is.

President Massie: Thank you, Mr. Podeyn, for the paper on this new subject. I am quite sure it is new to most of us.

The next speaker is the last speaker on our program. We do have a movie following him. I think in some respects it is very fitting that this speaker come at this time. We have been talking in terms of our own work, thinking in terms of our National Society.

We have been fortunate to have our neighbors and friends speak to us. Our next speaker is to talk to us in terms of the International Society. There is no one, I believe, who is any better qualified to talk to us.

Dr. Scherpbier is Secretary-General of the International Society, and when because of duties of state the President was not available, Dr. Scherpbier carried the entire load. It is with much pleasure that I introduce to you Dr. Scherpbier.

Dr. B. Scherpbier: Mr. President, Ladies and Gentlemen: First of all, as President of the Netherlands' Society of Photogrammetry, I convey our most cordial greetings to you and our best wishes for the welfare of our big brother, the American Society of Photogrammetry.

It is a great pleasure for me to have the opportunity to attend your annual meeting and it is a great honor indeed be to allowed to say a few words at this gathering about the Sixth International Congress and Exhibition of Photogrammetry which will be held in The Hague in September 1948.

In 1936, when on a visit in Washington, a number of the members of your Society met together to hear me tell something about an aerial survey in New Guinea which had commenced in 1934 and which was one of the first aerial sur-