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The Brock Brothers and the Brock Process*

Memorial Address

Foreword

This, the fifth of the Memorial Lectures, attempts to reconstruct the character and vision of Arthur Jr. and Norman H. Brock who, with Major Edward H. Cahill, their principal designer and co-inventor, were the American pioneers in aerial camera and mapping instrument development. Regrettably, most of their personal papers were lost or discarded following their deaths, but diligent search of other sources provides an insight into their personal and professional lives. Further, the files of Major Cahill, graciously made available to the author by Mrs. Cahill, following his death in 1974, complete the picture of early trials and successes for these pioneers. Additional facets are polished by this author's reminiscences of the Brocks, the personal recall of the sole surviving sister, Mrs. Francis A. (Louise Brock) Lewis, and papers from the files of Aero Service Corp. This Address follows the completion of an Archive in memory of the brothers, copies of which have been deposited with (1) the Library of the International Society for Photogrammetry (c/o Professor Anthonie Jan Van der Weele), Enschede, The Netherlands; (2) The Smithsonian Institution, National Museum of History and Technology, Washington, D.C.; and (3) The Franklin Institute, Philadelphia, Pennsylvania.

This is a Philadelphia Story—about a family, a tool works, and a mapping process.

Arthur Jr. and Norman H. Brock were, respectively, the third and fourth sons of John William Brock and Mary L. (Tyler) Brock. John W. Jr. was the oldest and he alone of the four is not a participant in our story. Sidney F. T. Brock, the second son, is vital to our account because of the confidence and financial support extended to Arthur and Norman by Sidney's investment banking firm, Reilly, Brock & Company. Louise Brock, only sister in the family, was much younger and this circumstance limits personal recollections which so often complete the fabric of a family saga. Lest some of you wonder why there were two "junior" appellations among the four brothers, let me hasten to say that Arthur was the namesake for a much-revered uncle, associated with the American Iron and Steel Mfg. Company in Lebanon, Pennsylvania, in the first decades of this century, later absorbed by the giant Bethlehem Steel Corporation. But, it was at American Iron and Steel that two young employees, Arthur Jr. and Edward H. Cahill met and formed a warm friendship that was to culminate in the development of an ingenious combination of mechanics and optics, the first American aerial cameras and, later, a mapmaking process.

The four sons did their undergraduate work at Harvard University, three emerging with A. B. degrees, and Sidney with a B. S. in mining engineering. John continued at the University of Pennsylvania, taking a law degree in 1908. His career—in Philadelphia—was spent in banking and the legal profession, except for U. S. Navy service during World War I, 1917-1919. John and Mildred (Mitchell) Brock had four children. John was born February 14, 1883 and died January 11, 1959, just short of his 76th birthday.

Following completion of his college years, Sidney spent about a year preparing mining reports on location in Nevada and

* Presented at the Annual Convention of the American Society of Photogrammetry, February 24, 1976.

Photogrammetric Engineering and Remote Sensing,
Vol. 52, No. 8, August 1976, pp. 1017-1034.

California. He returned to Philadelphia and entered the employ of stock and bond brokers. He progressed in this endeavor, and in 1913 he joined George K. Reilly, to found the investment banking house of Reilly, Brock & Company. It was this financial house which was so intimately involved with the fortunes of the Arthur Brock Tool Works and of Brock & Weymouth, Inc. Reilly, Brock & Company prospered and became a prestigious member of Philadelphia's financial community. They shared the premises at 1607 Walnut Street with the aerial mapping firm, while Arthur's Tool Works was located at 533 North 11th Street. Arthur, Sidney, and Norman collaborated closely in prescribing for the growing pains of the two engineering companies. It was natural that Sidney concern himself with the intricacies of balance sheets and money needs. He was a thoroughgoing businessman, rigorous and conservative in the handling of financial matters. Taking nothing for granted, despite eloquent testimony from his engineering brother-associates, Sidney sought his own impartial advisors to enable him to make measured judgments regarding the technical competence and the business prospects for the Brock developments. The old established and distinguished Philadelphia firm of consulting engineers, Day & Zimmermann Inc., probed the accomplishments of the two operating companies and reported at intervals to Sidney Brock. Later in this paper, some excerpted comments from one of their objective reports are made a part of this record.

Well established in business, Sidney Brock nevertheless sought service in this country's armed forces in World War I. He was a captain of field artillery with the 79th and 92nd Divisions of the United States Army, from May 1917 to January 1919. His stateside training camps included, by coincidence, Fort Sill, Oklahoma, the scene in 1915 of the first production test of an early Brock aerial camera, about which we shall learn later. Sidney served with the AEF in France and saw active service in the Argonne and Vosges sectors. In 1919 he resumed his banking mantle and continued to prosper with Reilly, Brock & Company until the collapse of the financial markets in 1929-30. Under circumstances linked to this debacle, Sidney F. T. Brock died on October 25, 1930. Born on May 5, 1885, he was but 45 years of age at the time of his death.

Arthur Brock Jr., the first of the two principal participants in our story, was born in Philadelphia on January 12, 1887. After preparation at St. Paul's School in New Hampshire, he graduated from Harvard in 1908. Though all his education was academic in nature, he showed an aptitude for mechanical development, and the handling of tools and machines. His early employment was with the J. G. Brill Car Company and the Lehigh Coal & Navigation Company, both of Philadelphia. In 1910 he became the Assistant to the President of American Iron and Steel in Lebanon, Pennsylvania, the firm previously noted. He and Edward Cahill left American at the end of 1913 to start the Arthur Brock Jr. Tool & Manufacturing Works. Brock and Cahill were soon involved in producing gunsights and fire control equipment for the Ordnance Branch of the then so-called War Department. Despite severe limits on appropriations in those years, the outbreak of war in Europe in 1914 enabled some of the future-minded military staff to prevail upon Congress to provide funds for necessary procurement. Arthur was already thinking and planning ahead. But, at this point, the story of the Brocks is comingled with the accounts of events told in the writings of Edward Cahill. We digress here to portions of Cahill's letters, written years later——

"In the summer of 1914 the declaration of war in Europe caused sudden, but temporary, upset in most manufacturing companies in the United States. At one time Arthur Brock conceived the idea of taking panoramic pictures through the optical system of submarines for viewing the ocean surface. Subsequent investigation disclosed that the Allied countries had no compelling need for submarines and that the German submarines were doing a lot of ship sinking without panoramic pictures.

"It might be well to point out here that Arthur Brock was ahead of his time in many of his ideas. Perhaps it was well that he did not have an engineering education, because he might have concentrated on a few ideas and not found other useful ones. He was quick in gaining another's thoughts and was persistent in carrying a development to the finish.

"The War had started (1914) and Arthur Brock came in one day with the idea of taking pictures with a camera suspended over a hole in the floor of an aeroplane.

The purpose was to obtain information of the battlefields in Europe. I had, in 1906, made a map (ground survey) of a portion of the V.P.I. Campus (Virginia Polytechnic Institute at Blacksburg, Va., where Cahill was a student of engineering)*, and the buildings (and other detail) were located on a plot by triangulation (Figure 1). I could see at once how, from two stations in space, points could be plotted (using overlapped aerial photographs). An enemy's battey or other position could be located relative to the attacking artillery, and then fired upon.

"It is desirable to point out that none of us had ever heard of taking picutres from aeroplanes. The idea was original with us and we believed that no one had given thought to aeroplane photography. It developed later that pictures had been taken from balloons, but not from aeroplanes.

"Scheimphlug of Austria developed the method of reprojecting a tilted picture, to a picture that would have been made had the lens axis been perpendicular to the plane of the object (ground). But his pictures were tilted through known angles in his seven-lens camera and he disclosed no method of finding the tilt of a camera in space. This problem was solved in the development of the Brock process.

"In October 1914 I started on the design of the first mapping camera carried on an aeroplane in the United States and perhaps in the world. It is true that pictures had been taken while holding the usual cameras of the time over the side of an aeroplane. But these photographs were useless for making maps. The camera was constructed at the Sloan and Chase Machine Shop, in Newark, New Jersey. At that shop we met Neils Pedersen, shop superintendent, and later he was persuaded to join us. None of the other men in our group had any idea about Surveying. It was just a matter of 'photographs' with them.

"At the time no one seemed to know what would be required of such mapping cameras, except that the field commander would want pictures as soon as possible after his orders were issued. This haste introduced the idea of ferrotypes. The camera designed was driven by an electric motor and provided with a gyroscope to keep the lens axis in the vertical. The ferrotypes were conveyed from a magazine

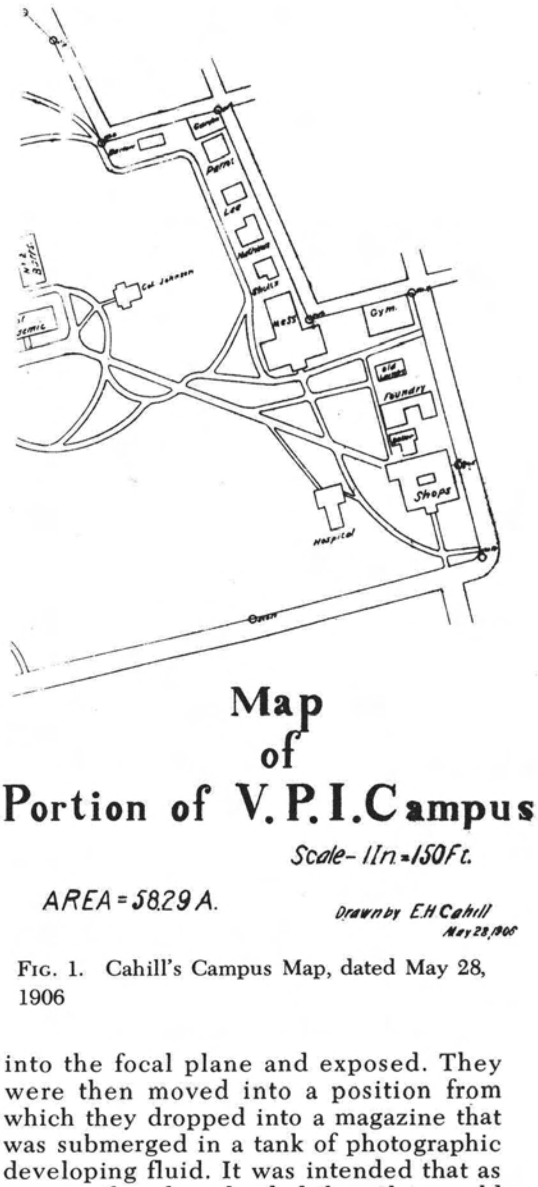

FIG. 1. Cahill's Campus Map, dated May 28, 1906

into the focal plane and exposed. They were then moved into a position from which they dropped into a magazine that was submerged in a tank of photographic developing fluid. It was intended that as soon as the plane landed the pilot would withdraw the magazine of exposed ferrotypes from the tank and plunge it into fresh water to stop the developer action.

"When the camera design was well underway, Mr. Lodewyk J. R. (Louis) Holst who had experience in making slot machines for automatic taking of ferrotypes joined our company. Because of slow emulsion he recommended use of 12" focus lens, f:4.5, made by Wollensak Optical Company, to cover a 4 × 5 inch image which was standard size of ferrotypes.

"The camera was completed in the spring of 1915. The gyroscope was never taken into the air. While its performance

* Passages in parentheses, for clarification and completion, are this author's.

as a gyroscope *per se*, was good, it proved that such a device would not hold the lens axis near enough to the vertical. It was also found that the compelling haste for use of ferrotypes would not exist. Without any change in the camera, metal holders of the size of the ferrotypes were made to receive cut film. No change was needed in the magazine except no liquid was placed in the camera tank. The 4 × 5 inch image size was standard for commercial film.

(Patent application for this camera was filed on December 10, 1915, by Arthur Brock Jr., L.J.R. Holst, and A. J. Mottlau, co-inventors; Patent No. 1,331,978 was granted on February 24, 1920, more than 4 years later. This is one of the 19 patents granted to Brock and his associates, listed in another part of this Address.—Author)

"In the summer of 1915 the camera was taken into the air for the first time at Fort Sill, Oklahoma by Captain Benjamin Foulois, later Major General, Chief of the Air Force, with the pictures showing positions of buildings near the Fort. These were accurately plotted on existing maps; also, photo maps (mosaics) were made with prints made from the films. A reproduction of one of the mosaics of Fort Sill appears on page 113 of the *Journal of the Optical Society of America,* March 1932.

"Among other things, experience from the flight proved that the camera had little volume for taking large numbers of pictures that would be needed in wartime. Therefore, it was decided to expend efforts on a lighter-weight camera for use of roll film. The new camera was completed in the Spring of 1916, in our machine shop in Philadelphia, under supervision of Neils Pedersen.

"The camera was driven by a spring motor of sufficient stored energy per winding, to expose 100 pictures in a single roll of film 4½ inches wide, by about 560 inches (46 ft.) long (Figure 2).

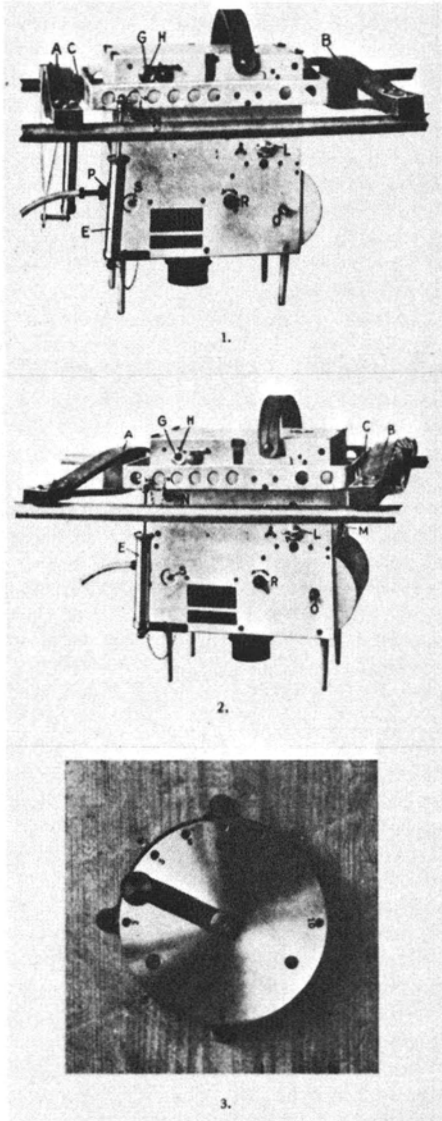

Fig. 2. First Brock Film-roll Camera —1915

The camera was hung pendulously in a gimbal and excessive oscillation damped by hydraulic dashpots which also allowed the lens axis to approach the true vertical. The speed of the motor was controlled by a centrifugal governor. The speed of taking pictures was by a timing device controlled by a pendulous disc. By means of a flexible shaft this device was connected to an instrument on the pilot's instrument board. By placing the lever of this device on relative positions, the pilot could take pictures at any rate, from 3 to 10 photographs per minute. The camera was fully automatic and required no attention by the pilot operating the plane. It was designed for a one-man aeroplane."

J. Victor Dallin, an early photographic pilot and later owner and operator of Dallin Aerial Surveys, in Philadelphia, who flew the first of the Brock cameras, gives us a vignette: "Arthur and Norman were very large men ..... they drove about in an old Ford open car ..... the car was crowded most of the time with staff and equipment. Arthur always paid the bill for lunch for a group of us during that early research period. They were both fine men and their business on North 11th Street was well organized and operated. I did their flying in an old JN4c, a Canadian version of the World War I 'Jenny'. It was powered by a 90 HP Curtiss 0.45 engine. Our experimental flights were usually about 5000′ altitude and the Brock camera was set up and pre-arranged to operate by the pilot, with automatic control for exposures. The plate (film) size was 4 × 5 inches. Later, the Brocks employed a crew consisting of Ralph Smith, pilot and Ernest Buehl, cameraman, flying a Fokker cabin aircraft."

We return to Major Cahill's account: "About the time this first model design was started, the question concerning the source of film worried us since it was thought that a manufacturer would not care to change from existing film sizes. However, we decided to consult Ansco first because we understood this company was the pioneer in making photographic film. The Ansco people agreed at once to furnish the film and no other manufacturer was approached.

"When the first film camera had been corrected to finally give satisfactory, dependable performance, war, or near-war, started with Mexico. We then designed a field tent to house our laboratory for the border war. The tent was lined with black cloth and was provided with a window of turkey red cloth and also one of orange color.

"In the summer of 1916, the tent laboratory and the mapping camera were taken to the Mexican border by Arthur Brock and his brother Norman H. Brock. It is a very interesting fact that the first aerial mapping of the U. S. Army was assigned to the Ordnance Department. In fact, the first aerial mapping force of the U. S. Army consisted of two civilians, Arthur Brock and Norman Brock and an Ordnance Department Sergeant, in command of James L. Walsh, 1st. Lieut. Ord. Dept. U. S. Army. He was one of the founders of the American Ordnance Association and was its President at the time of his death in 1952. The pictures were the first to be taken by the Army in a mapping camera during war.

"About 1933, Colonel Walsh sent me a number of films that were exposed in 1916. In 1949 he asked to borrow some of them. It was at this time that I learned some of my records, among other cartons, were stolen while my household effects were being moved to my present home. I regret that such early records were lost.

"In 1916 Arthur Brock and I worked on the design of a new 100-exposure, roll-film camera, with Pedersen as project manager. In June of 1917, I took one of the new 100-picture cameras to Langley Field, in Virginia, for testing. A civilian pilot—Smith by name—took me up with the 100-exposure camera. ("Ralph" Smith later became one of the first and most proficient mapping pilots with a civilian organization.) We reached 5000 feet (a record of sorts in 1917), at which elevation I exposed all the film." (How unfortunate, for the sake of the early history of aerial photography in the United States, that this record is buried, perhaps forever, in the dusty files of the past; nor is there any mention of this early effort in General Geo. W. Goddard's book, *Overview*.)

"Shortly thereafter, in October 1917, I accepted a commission as First Lieutenant with the Ordance Department of the U. S. Army. Because I became involved in the phase-out of wartime contracts and claims, as the War ended, I was not able to obtain my discharge from the service until July 1, 1921. The Arthur Brock Tool & Mfg. Works had become the Precision Engineering Co. and I assumed the duties of Chief Engineer. I worked on precision machines and dies, but more particularly, developed a method for making aerial maps, and designed the optical-mechanical instruments for performing the process. (This was the year—1921—that the Brock Process came into being (Figures 3 and 4)).

"Norman H. Brock, a younger brother, had joined the company during this period, and was associated principally with the establishment and furthering of the mapping operations. Holst collaborated with Norman Brock in the preparation of several patent applications, did most of the writing, and added his name to several applications as co-inventor with Arthur Brock, Jr. (The application for patent, for the first glass plate camera, on November 9, 1923 and granted October 20, 1925, No. 1,558, 272, titled Aeroplane Camera, names Niels Pedersen as Inventor—Figure 5). The camera patented in the names of Brock and Holst was never made. Holst showed a gyroscope installed inside the camera. It could not operate properly because the precession would just wobble the camera."

We return to Arthur Brock and from his

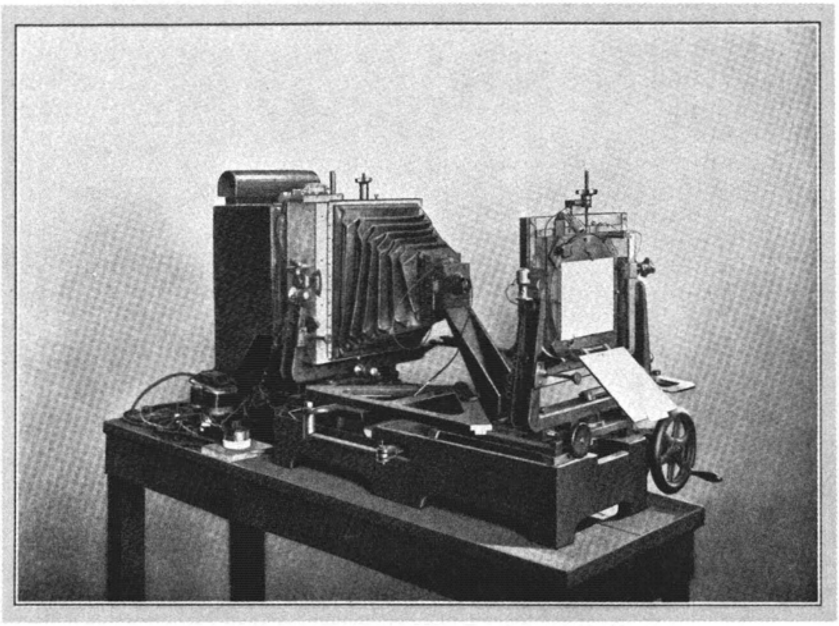

FIG. 3. Brock Plate Reproduction Instrument—1921

own accounts of events, written in 1933, we quote him:

"In late 1913, I started for myself in a small way in Philadelphia, becoming interested in originating mechanical devices. Eventually my efforts resulted in Arthur Brock Jr. Tool and Manufacturing Works. The firm prospered and stood first on Production list (*sic*) of the U. S. Ordnance Department, for gunsights and fire control apparatus. I was interested in developing War-related devices and this led to cameras for use in aeroplanes, in 1915, and mosaic (photomap) processes. A later type of camera, developed in 1917, was adopted by the French Army. In 1916, I had tried unsuccessfully to persuade the British

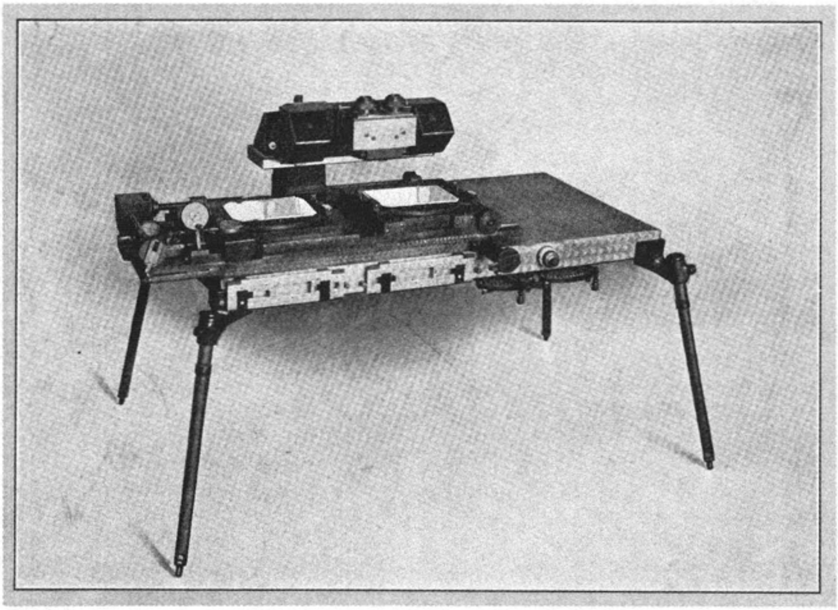

FIG. 4. Brock Stereoscope—1921

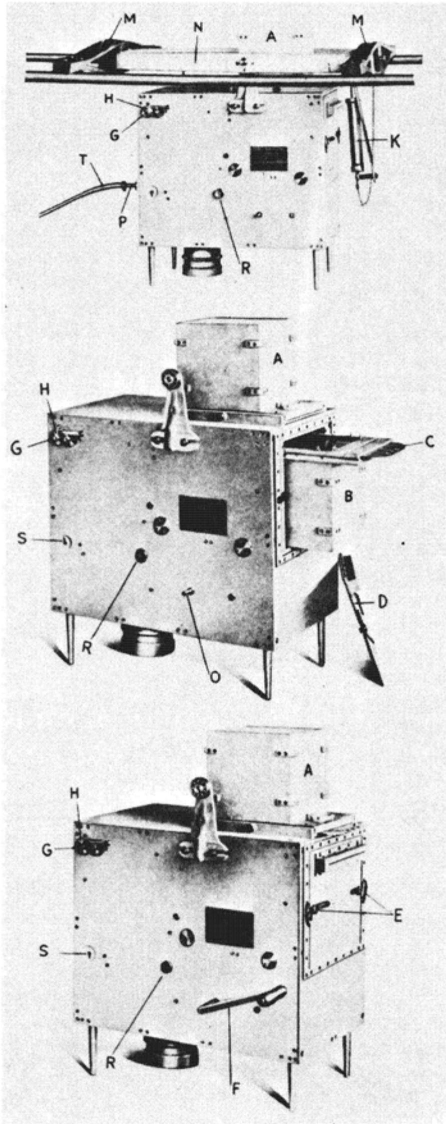

FIG. 5. First Model, Brock Glass Plate Camera—1919

Army to use my camera, but in any event, this effort assisted in their decision to use aeroplane photographs. Later, failure to receive prompt settlement of government procurement contracts was a financial catastrophe and I decided to pursue the development of aeroplane photography into a map-making system. Many difficulties were encountered, but eventually we had success.

A subsidiary company, Brock & Weymouth, Inc., with offices in Philadelphia, was organized in 1925. But I was in serious disagreement with other parties of interest and withdrew from the business in 1926. The name of the machine shop was changed and my name dropped after I left. (The Tool Works became the "Precision Engineering Company" and still later, the "Precision Manufacturing Company," all located at 533 North 11th Street. It is unknown when this company ceased business, but correspondence in the author's possession dated July 5, 1938, shows Mr. Neils Pedersen, hired by Arthur in 1915, as the manager of the business.)

"In the fall of 1923 I contracted pneumonia, and on a trip to California for my health in 1924, I was married quietly. Some time afterwards I returned to Philadelphia, but the strain of business disagreements noted, was too much for me. After six months' rest in 1926, I tried an enterprise in Detroit, but finding the climate too severe for my condition, I moved to California. There, I found it difficult for an Easterner to become established in Southern California, especially with my impaired health, so in 1930, I accepted full retirement."

To complete the record, we know that Arthur Brock married Frances M. Goehler of Santa Ana, Calif. on March 4, 1924. They made their home in Hollywood, California. There are no records of his retirement activity or business interests, if any, but he returned eventually to Philadelphia, where he died on February 10, 1943, at age 56, survived by his wife and members of the Brock family. There were no children.

Norman Hall Brock, the youngest of the four sons, was born at Wyncote, Pennsylvania on April 23,1890. He received his preparatory education at the DeLancy School in Philadelphia, and then earned his A. B. degree at Harvard University in three years, graduating in 1912. He started his business career as a bonds salesman and, by his own admission, with limited success. The outbreak of war in Europe in 1914 propelled Norman into vastly different, exciting activity. We turn to Norman Brock's own accounts to learn about his wartime and professional activity during the next 15 years.

"Within 30 days of the declaration of war in Europe, I went to England to sell to the Allies the then new art of aerial photography. Air forces had not until then been of recognized usefulness. Most of the superior officers were 'high rankers' for whom there was no command, and usually cavalrymen, so they were put in charge of air forces. It took nearly a year of frequent trips across, with apparatus and much persuasion to get very far.

"The original idea of an automatic military camera was my brother's, Arthur Brock, Jr. He and I and two engineers (L.J.R. Holst and Edward H. Cahill) worked intensively to develop a small automatic camera that could be used and operated by the pilots of the faster planes, which were gradually becoming known as pursuit ships. Through the influence of General Leonard Wood of the United States Army, we had the cooperation of the tiny U. S. Air Force (the Signal Corps in those days).

"At last we developed a camera that met the military requirements and from whose photographs actual artillery ranges, etc., could be obtained. These were put into production. The French were the first to use them. All told, their use took me to five of the Allied Armies. Finally, I hooked up with the Section Technique of the French Aviation organization. I recall that one of my assignments was a two months' fruitless search for the Germans' 'Big Bertha' cannon, which shelled Paris. Later, I went to the Italian Air Staff and then back to the French Artillery. (It was undoubtedly Norman's service with the French which enabled him to obtain approval and to execute, in 1926-1927, a test map, by the Brock method, of an area at Gasny, France. The scale was 1:10,000 and contour interval 3-meters. The sheet, 22 × 25 inches in size, was drawn and reproduced in colors. The only extant copy, to the author's knowledge, is bound in copy No. 1 of the Brock Archive, previously noted. In the same time period, Norman Brock made a similar test of an area at the town of Vecchiano, Italy. No copies or details of this photogrammetric survey survive, but a small illustration appears in the article "Topography From the Air," by L.J.R. Holst, presented as a lecture February 23, 1928 and printed in the *Journal of the Franklin Institute*, Philadelphia, Vol. 206, No. 4, October 1928.)

"War Record: Enlisted at Paris, Private, 2nd Class (Fontainebleau Artillery School), November 2, 1918; 3rd Regiment Artillerie de Campagne (75's), January 22, 1919. In March, 1917, went to France under contract with French aviation until I enlisted in French artillery in the Fall of 1918. Overseas service, including that with French aviation, March 1917—February 10, 1919. Discharged at Paris.

"After the War we continued our studies with aerial cameras, hoping to be able to make actual topographic surveys from the air. It took years of research before we were able to build suitable instruments so that we could actually make a topographic map of terrain that might be anywhere. (First test area near Media, Delaware County, Pennsylvania, was successfully completed in 1922, using the first and earlier models of the Brock instruments.) These maps were as accurate, or more so, than surveys made on the ground by engineers. Power companies, lumber companies, railways, and the United States Government used our maps. For development work and the process, our Company, in the person of its Chief Engineer, was awarded the Levy Medal of the Franklin Institute of Philadelphia, whose awards in science are probably second only to a Nobel Prize.

"Of course, after aerial photography got past the hand camera stage, everyone claimed its origination, but patent suits proved that we were first.

"When the Depression came our customers ceased to build new works and thus required no maps. However, the Flood Control map of the Wabash (and White) River that we made in 1928, was the basis for flood control works that helped contain the great flood of the Ohio River basin in 1937. We also completed in 1930, air topographic maps by our process, on which the Boulder (Hoover) Dam and reservoir were based.

"Since the company ceased business, I have spent my time on research and development in photography, motion pictures science, and recording devices."

Norman Brock remained in the Philadelphia area for several years and then relocated to New York City. For many years he was associated with the Edwards Engineering Company, 21 Yenicock Avenue, Port Washington, Long Island, New York. He resided in Manhattan. He was engaged in electronic engineering activities with the Edwards Company. He had previously worked with the D. R. Bradley Company in New York. He authored and published a number of engineering reports. In 1962 he summarized his work in these latter years as "invention, research and experimentation ..... My philosophy of living is that practically nothing is impossible and to accept what I cannot change."

Norman died on January 29, 1969 in

New York, at age 78. He never married.

Returning to the Brock Process, descriptions of the optical, mathematical, and mechanical principles underlying the development of the Process and the details of operation of the glass plate camera and the several instruments have been so thoroughly documented, as the included bibliography attests, that it would be redundant to recount their development here. Hopefully, the accompanying slides should enable us to visualize the appearance and *modus operandi* of the mapping system. Most thorough of the many publications describing and documenting the Brock Process is the article by Major Cahill, the individual who made the greatest contribution. The audience is referred to Cahill's story "Brock Process of Aerial Mapping", presented as a lecture before The Optical Society of America, on October 29, 1931 at Rochester, N.Y. and printed in the Society's Journal, Vol. 22, No. 3, March 1932.

Throughout the World War I years and well into 1921, Brock, Cahill, Holst, and Pedersen continued their experiments and instrumentation with the goal of developing a method for making topographic maps from aerial photographs. The knowledge gained from those efforts led to three basic conclusions, which this author cautions must be considered in the context of the period of reference:

(1) In making topographic maps from aerial pictures, some operations can be performed without the use of a machine, and those operations performed on machines do not require the same amount of time. Therefore, a single machine performing all operations would not be economically successful, as its output would be limited by the operation requiring the most time.
(2) Because of liability of relatively large errors introduced by angular displacement of optics, due to lost motion and deflection of supporting members, non-movable optical systems should be used where possible.
(3) That, until film free of non-uniform shrinkage or expansion is available, aerial pictures should be made on glass plates, for accurate determination of contours.

The discrete steps, or operations, which constituted the Brock Process were (a) producing aerial photographic negatives on glass plates, (b) plotting the horizontal position of the photographs, (c) horizontalizing, or tilt, correcting the photographs, (d) contours and culture delineation, (e) scale equalizing, and (f) assembling the photographic information into final map form. The field work for horizontal control and for use in horizontalizing photographs was included in operations (b) and (c), respectively.

The aerial camera (Figure 6) was provided with interchangeable magazines containing 48 plates, 6.5 inches by 8.5 inches, especially selected glass stock. The camera was hand-operated, but stabilized by hydraulic dashpots. After laboratory development, the photographs were enlarged to two diameters on glass to facilitate accuracy in plotting of horizontal positions, tilt correction, and drawing of contours and cultural detail. The enlarging was accomplished on a precision-type instrument, the Enlarging Projector (Figure 7). Overlapping pairs of plates were then placed on a large stereoscope (LS) for preparation of transparent paper "templates." A marking tool permanently mounted on the stereometer was positioned optically and both the plate emulsion and the vellum paper overlay were perforated at conjugate centers, at control points, and at extremities of "baselines" whose lengths and azimuths were field-determined. The templates were then removed from their underlying plates and were used in developing a classic radial-line plot for either a strip or block area of photographs, depending on job requirements. Because of consistent success in achieving very small average tilts in the photography, it was rarely necessary to horizontalize an exposure for developing the radial line plot. In plotting the horizontal control, it was necessary to correct for tilt only to determine the vertical or nadir point of the picture, which was then used as the "origin" in the plotting template.

The next operation was "correction" (Figure 8). Major Cahill states in his article "The fundamental difference between the European and the Brock methods of solution is that knowledge of only the elevations of ground points is necessary in the Brock method, whereas data for both vertical and horizontal positions of points are required by the European methods. In the Brock Process use is made of the relation that in a stereoscopic pair of vertical photographs, the coordinates of corresponding images will be in agreement."

In the Process use was made of charts printed on transparent plastic depicting, on curves, the angles at which the focal

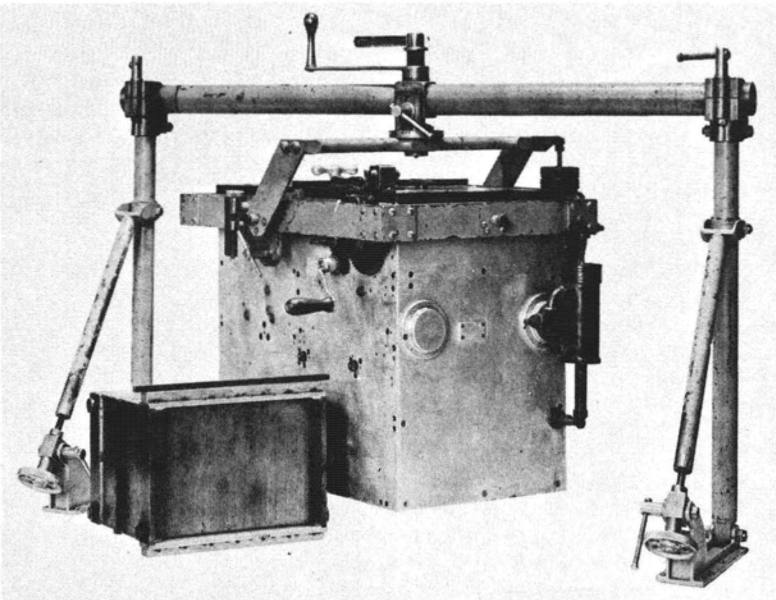

FIG. 6. Brock Plate Camera, with 48-plate magazine

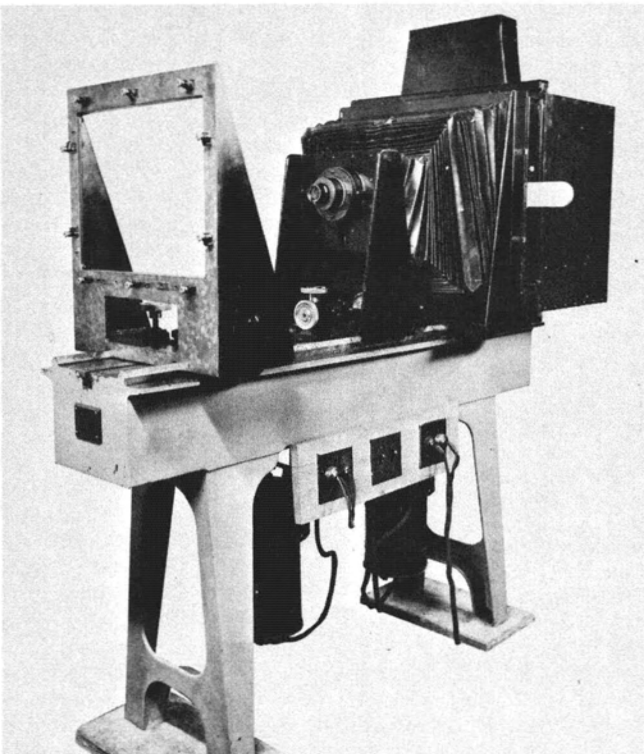

FIG. 7. Brock Enlarging Projector—1925

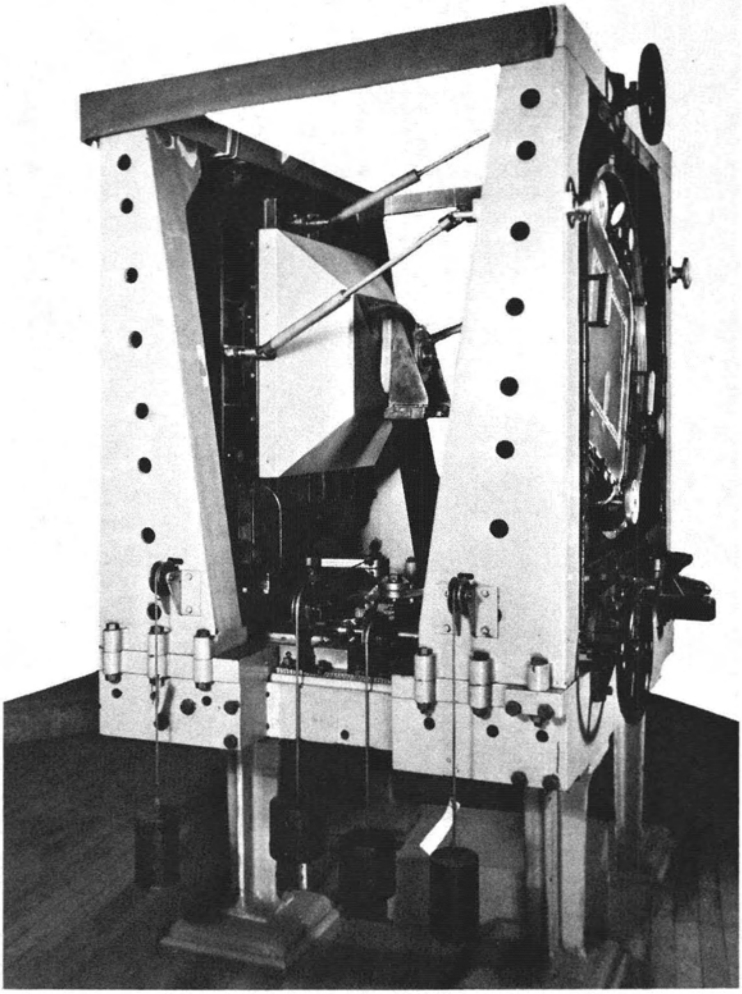

FIG. 8. Brock Correcting Projector—1925

planes of the correcting projector must be tilted in order that the projected image of the aerial photograph will be a horizontal equivalent. There was no computing of angles of tilt correction in the Brock Process. Charts and tables had been constructed, in which the focus of the projector lens and the tilt angles were substituted for the camera focus and tilt. The charts were laid over each photograph of an overlapping pair, and they indicated the necessary tilts that would displace the conjugate image of salient points in such amounts and directions as would eliminate the excess in abscissas and ordinates. The step-by-step procedure has been best described by Major Cahill in his article, with the end condition being one in which the parallaxes and ordinates of the salient points are in agreement, and the pair of photographic images represent horizontalized pictures. Image focusing and measuring grid screens were then removed and replaced by sensitized plates that recorded photographically the corrected plate image.

The next operation, the development of contours and culture, was accomplished on a large stereoscope or stereometer, designated as "LS" (Figure 9). Topography and ground detail were drawn on a transparent sheet of specially-stabilized paper, superimposed on one of the photographs. Coordinate hand wheels brought all parts of the stereoscope model into view, without relative movement of the two photographs, and there was no movement of optics. The scanning of the model, the drawing of

FIG. 9. Brock Stereometer—1925

successive contours, and the tracing of ground detail was accomplished with the aid of two reticules in the optical system. The interplay of the vertical crosshairs served as the more familiar "dot" or "v-type" floating mark. The finished paper overlay, recording topography and culture in the overlap area, plus all control and orientation marks, was then removed for the next operation.

The stereoscope sheet was still a conic projection. It was inserted into another machine for scale equalizing, or converting to the orthographic (Figure 10). Consisting of a projection feature and light-table surface, the control and orientation marks enabled the operator to adjust to scale the successive contours with contiguous cultural detail. The resulting component template sections of map were then oriented and transferred to the base grid by tracing, by overhead projection instrument, or by other means. Customary procedures then brought the topographic map to editing and reproduction stages.

The American industry aspect of the Brock equipment is indicated further by

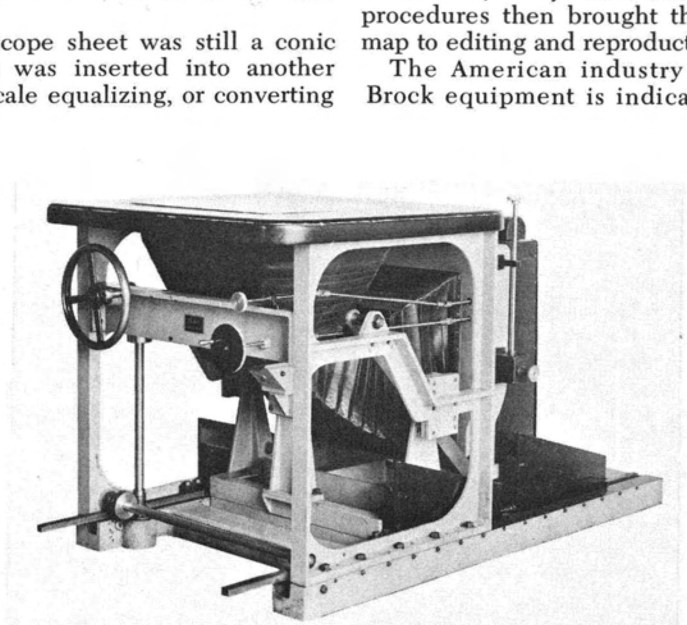

FIG. 10. Brock Tracing Instrument—1925

the use of lenses in all projection apparatus made by the C. P. Goerz American Optical Company, New York. The objectives and the relatively large prisms of the stereometers were made of American glass by the Boehmke Optical Company of Philadelphia, and the remarkably accurate grid screens were supplied by Max Levy and Company, Philadelphia. So that, excepting the camera lens, all parts of the equipment were made in the United States. The story of the optical elements would be incomplete if we did not acknowledge the unstinting assistance of the late Dr. Irvine C. Gardner of the old United States Bureau of Standards, Optical Branch. Dr. Gardner was of inestimable help in respect to lens evaluation and testing, and for his many helpful suggestions. Major Cahill's papers record a professional rapport and a warm regard for Doctor Gardner's scientific expertise.

The first models of the Brock instruments, assembled in 1921, utilized plates of the same size as produced by the aerial camera. Early photographs show these instruments (Figures 4 and 5). The 1922 test map of the Media, Pennsylvania triangle was produced on these machines (Figure 11). The Brocks and Ed Cahill profited rapidly from the early efforts and by 1924 the larger, more versatile, and more accurate instruments were ready for production. Continuous refinements were made in the selection and testing of optical components, in the photographic processing techniques, and in the computation of supporting mathematical tables, graphs, and grids. Methods for performing the several laboratory operations, the stereoplotting of topography, and the topographic drafting were under constant refinement.

The business and engineering staffs were expanded and organized to sell and produce contract work to standards acceptable to the engineering community. In 1924-1925, this expansion was of the utmost significance and included the following executive and production personnel:

Frank E. Weymouth, President
Norman H. Brock, Vice President

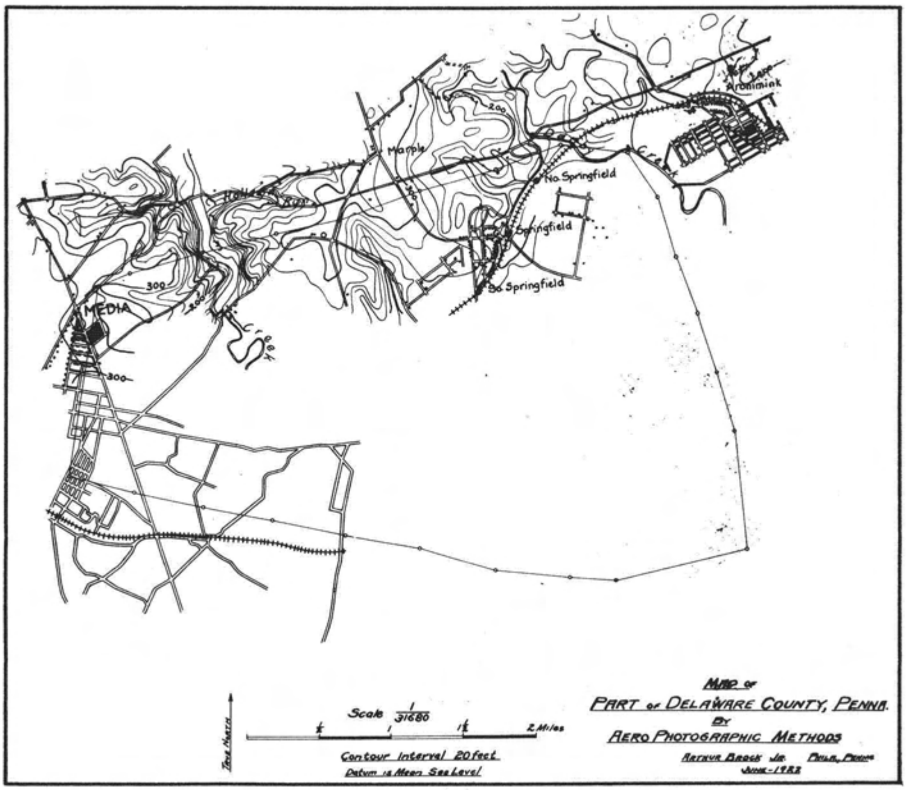

FIG. 11. Media, Pennsylvania Demonstration Map, 1922. First topographic map made in the United States by photogrammetric methods.

Edward H. Cahill, Vice President for Equipment Development and Methods
Thomas W. McKinley, Design Assistant to Edward Cahill
L.J.R. Holst, Consultant for Optics and Patents
J. B. Beadle, Sales Manager
Thomas P. Pendleton, Chief Engineer, Mapping Operations
Sidney H. Birdseye, Chief of Field Surveys
George Crowther, Production Manager
Allen L. Putnam, Accounts and Administration.

The "Weymouth" of Brock and Weymouth, Inc., was Frank E. Weymouth who resigned from the position of Chief Engineer, U. S. Bureau of Reclamation, effective October 31, 1924. Let us read the notice of his joining Brock and Weymouth as it appeared in the December 4, 1924 issue of *Engineering News Record*:

"F. E. Weymouth, who recently resigned the office of chief engineer in the U. S. Reclamation Service, has become president of Brock & Weymouth, Inc., an organization with offices at 1607 Walnut Street, Philadelphia. Mr. Weymouth graduated from the University of Maine in 1896 and since that time has been actively engaged in engineering work. His experience in waterworks, Nicaraguan canal surveys and railroad development in South America led to his selection for the staff of the Reclamation Service when it was formed in 1902. He carried out a number of government irrigation projects, including the Arrowrock Dam, among the highest in the world, constructed under his leadership for a million dollars less than the estimated cost. This success led to his appointment as chief engineer, in which position he has for years supervised engineering work in fifteen states of the West. Brock & Weymouth has been organized to furnish information for scientific studies of engineering projects, and for this purpose will utilize the Brock patented aerial process and equipment in making topographic maps, a process by which contours can be rapidly and accurately drawn on maps from photographic information."

Mr. Weymouth brought to the Brock brothers the business acumen and experience developed during a distinguished engineering career. He devoted his energies to business promotion and developing acceptance of the Brock methods by the construction industry. But, for a man accustomed to the challenge of major works and creative decision-making, the confines of his new job proved unacceptable. In less than a year, Frank Weymouth accepted the tremendous responsibility involved in designing a water supply system for the city of Mexico City, urged upon him by the Mexican ambassador. He resigned from Brock and Weymouth, but his name was retained. Norman H. Brock assumed the presidency.

The then revolutionary photogrammetric method for preparing topographic maps met resistance and ridicule from large segments of the engineering profession during the mid-1920's. This is often the price paid by innovation and pioneering. These were also years when private enterprise also meant private funding. The contribution made by Reilly, Brock and Company has been told. The great outpouring of funds for research and development in the United States was to begin much later, primed by the first rumblings of War in Europe in the late 1930's. Ironically, the public works programs of the New Deal, starting in 1933, initiated a series of mapping projects, a small portion of which would have sustained the Brock organization. But Brock and Weymouth closed its doors in 1931, the staff scattered and the equipment was consigned to dead storage. The acquisition of the complete assets by Mr. Virgil Kauffman, in 1938, for operation by Aero Service Corporation, initiated a period of successful and profitable operation, which did not end until obsolescence dictated its permanent retirement as a competitive mapping process, in 1952. There were bright spots of endorsement in the early years, of which these are examples:

(1) From Day & Zimmermann, Inc. to Sidney Brock, dated June 4, 1924 "... Our connection with this work (The Brock Process) dates from the Spring of 1921, at which time Mr. Arthur Brock, Jr. and his associates had already developed and used a camera designed to take a series of overlapping photographs... and a machine or instrument designed to mount two adjacent photographs in such manner that they can be viewed in third dimension, and to measure both horizontal and vertical distance in the picture.... These machines were used in a series of tests by our engineer, which permitted investigation of the theories upon which the process is based. These were found sound and their utilization and the finished map resulting from their use are limited only by the op-

tical and mechanical perfection of the apparatus used. . . . The first checking done by our engineers was upon two areas, the first covering a small section around Georges Hill in Fairmount Park, and the second a mile-wide strip around a triangle approximately four miles on each side, lying between Lansdowne and Media (Pennsylvania). . . . The traverse checked back on its starting point with exceptional accuracy. . . the aeroplane photographic survey coincides throughout with the instrumental survey map to a highly satisfactory degree."

(2) Letter from Mees and Mees, Engineers, Kinney Building, Charlotte, N. C., dated August 16, 1924 to Norman H. Brock: "Since receiving the map of the Saluda area, I am a firmer and more enthusiastic convert to the aerial photographic method than ever. I feel sure that we are destined to open the eyes of the engineering world at sometime in the near future, when you feel that the time is ripe for publicity. The Engineering Faculty of the University of North Carolina is already deeply interested in the subject." (signed by H. R. Faison, Resident Engineer).

(3) Letter from Professor Arthur W. Goodspeed, Randal Morgan Laboratory of Physics, University of Pennsylvania, Philadelphia, dated January 8, 1925 to Brock and Weymouth, Inc.: "Some time ago, at the instance of Mr. Sidney Brock and of Mr. Charles Day of the engineering firm of Day and Zimmerman of this city, I investigated the Brock Process of Topographic Mapping, involving aerial photography, reproduction of such photographic plates as may have been exposed with the camera slightly tilted away from the vertical and stereoscopic treatment of the plates in pairs.

"I visited the shop containing the apparatus employed in the process, inspected this and considered the various steps of the process from the aerial photographs to the point of the finished map.

"The purpose was to form an opinion as to the soundness of the theories on which the operations of the machines depend. I have considered these theories and verified the mathematical relations involved. As a result, I wish to certify that to the best of my judgment and belief the process is sound in all detail as to the physical laws and mathematics involved, that a survey and topographic map of a ground area can by this process be made with superior accuracy, that the method must prove vastly more rapid and far more exact in detail than maps made in the usual processes of surveying. The application of this new process is obviously universal and unlimited."

(4) Letter from U. S. Geological Survey, dated April 15, 1927, signed by C. H. Birdseye, Chief Topographic Engineer (relative to authorized demonstration project for the Brock Process, portion of Bushkill, Penna. quadrangle). "It has been interesting to bring together the two maps independently made, one by our ground method, the other by your aerial method. . . . The most general difference is due to the marked superiority of the photographic method in refinement of detail. . . . These comparisons are strikingly favorable to the map by your process. . . . You have demonstrated most convincingly the accuracy of the Brock Process of topographic mapping and I hope it will be feasible to make its products increasingly available to engineers and others who are interested in more accurate maps."

The period of greatest activity for the Brock engineering company occurred in the years 1929-1930, and this included the first 12 months of the Depression. The job with the largest area of topography, including hydrographic data, was that completed for the Wabash and White River valleys in the State of Indiana, for the U. S. Army, Corps of Engineers, Louisville, Kentucky office. (T. P. Pendleton's article "Photomapping the Wabash", tells that story.)

The next job, less in total area but infinitely more detailed with overhanging, convoluted, and shattered rock surfaces (Figure 12), was that completed for the United States Reclamation Service, for Hoover Dam and Reservoir, on the Colorado River. (J. B Beadle's article, "Air Survey for Hoover Dam", describes that undertaking.)

In late 1931, Brock and Weymouth's assets were placed in the care of Mr. James B. Harper, an investment banker and former employee of the Brock firm, as Assignee for creditors. In the period 1931-1938, Mr. Harper was most diligent in conserving the assets of the company and in pursuing every inquiry and possibility for the sale and activation of the dormant equipment. He also continued to monitor, with Edward Cahill and the patent attorneys, the progress of Cahill's final patent application (filed July 25, 1930) for *Ap-*

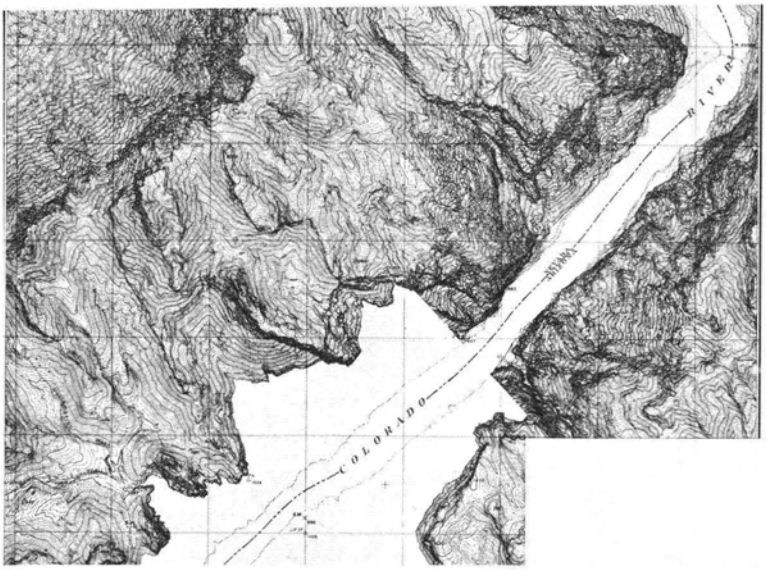

FIG. 12. Portion of Sheet 1 (of 9), Hoover Dam and Reservoir project, 1931, illustrating intricate rock topography (5-foot contour interval).

paratus for Correcting Tilted Photographs, No. 1,911,142, granted May 23, 1933.

In the year 1938, encouraged by the burgeoning mapping industry and his characteristic vision, Virgil Kauffman, President of Aero Service Corporation, developed with the assignees a realistic financial plan for acquiring the complete assets. The purchase was duly accomplished and the equipment, materials, and files were moved to Aero Service's plant in Northeast Philadelphia.

Mr. Kauffman recruited several of the former Brock personnel to work with Aero's technical staff, to activate and refurbish the equipment and to train others in the techniques of operation. After this period, Aero's staff of engineers and technicians undertook increasingly complex and extensive work projects. They also simultaneously developed improvements and efficiencies in the equipment and the working methods. These innovations significantly extended the economic life of the Brock Process.

The completes our portion of the Philadelphia Story, spanning the years 1913-1931. It is fitting that this uniquely American development, in what was then an esoteric field of technology, be made a part of the record. We have identified the men who exercised the vision and suffered the disappointments, and have also noted their moments of reward. Photogrammetry in the United States has been the richer for this experience.

Representative sampling of mapping projects, 1922-1930:

(1) (first test area) Media-Springfield, Delaware County, Pennsylvania—strip area. 1922.
(2) (2nd test, the first compiled on new advanced models of equipment) Media—Drexel Hill—Morton area, Delaware County, Pennsylvania 1924.
(3) (first contract job). Green River Area, Greenville, South Carolina, Mees and Mees Engineers, Charlotte, North Carolina 1924 (Figure 13).
(4) Saluda Development, Green River, North Carolina, Mees and Mees 1924.
(5) Power project survey, head of Saguenay River, Chicoutimi, Quebec, Canada 1924.
(6) Damsite, Conowingo Dam, Susquehanna River, Pennsylvania for Philadelphia Electric Co. 1925.
(7) Railroad right-of-way surveys, Canadian National and Canadian Pacific Railroads 1927.
(8) Etowah River, Cartersville-Tate, Georgia. Georgia Power & Light Co. 1927.
(9) Power dam and reservoir mapping, Lewis River, Washington State 1928.
(10) Wabash and White Rivers, Indiana, for Corps of Engineers, 222 river miles 1929.
(11) Hoover Dam and Reservoir, Colorado River, Colorado—Arizona, U. S. Reclamation Service 1930.

Demonstration Projects—(additional to 1922-1924 Media, Pa. tests).

(1) 1927—Gasny, France, for French Army (Figure 14).

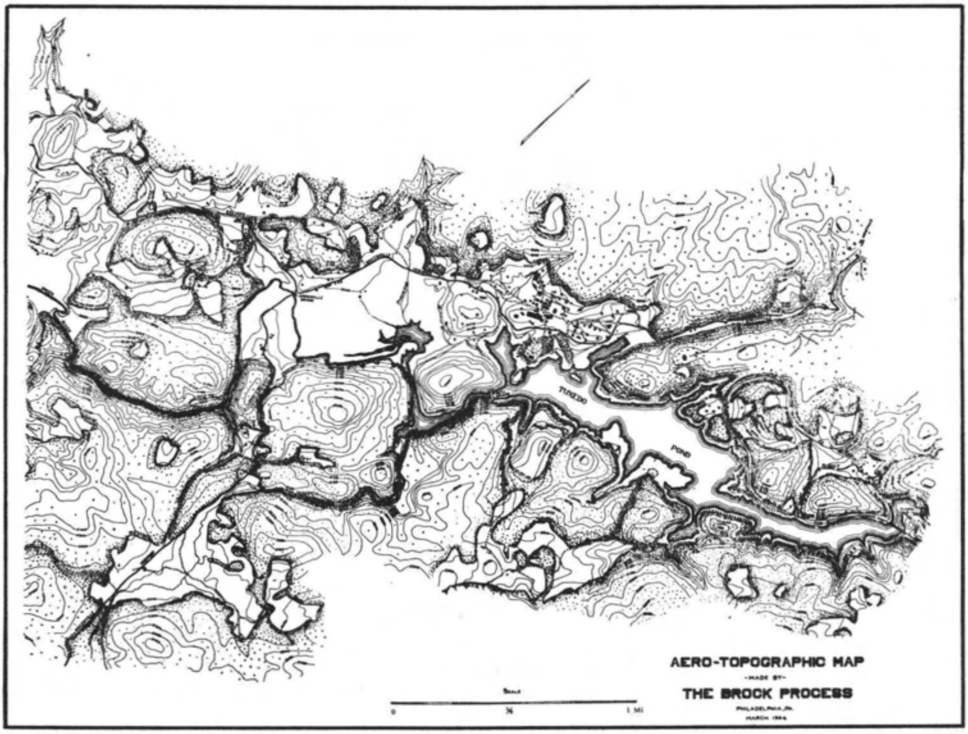

FIG. 13. Green River area, South Carolina, 1924. First photogrammetric mapping project in the United States for an engineering client.

(2) 1927—Vecchiano, Italy (Italian Government or Military Agency—exact identification not known).

(3) 1927—Bushkill (Pennsylvania) quadrangle, south one-third for U. S. Geological Survey, 20-foot contour interval, compilation scale 1″ = 1000 ft (See "Topography From the Air"—L.J.R. Holst, *Journal of the Franklin Institute*, Philadelphia, Pa., Vol. 206, No. 4, October, 1928, p. 470 and back cover fold; and letter dated April 15, 1927, from C. H. Birdseye, Chief Topographic Engineer, U. S. Geological Survey.)

(4) 1927—Estate of Richard Sellers, Bellevue, Delaware. Approx. 88 acres, compiled at scale 1″ = 200 feet, 1-foot contour interval. Culture symbols include individual bushes and trees. Original drafted in colored inks. (See same ref. as No. 3 above, pages 468-470 and cover fold, for comparative check profiles.)

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1,224,545	Means for Determining Ground Speed	5-1-17
1,300,114	Film—Cameras	4-8-19
1,301,873	Spring—Motor Controls	4-29-19
1,301,968	Spring—Motor Controls	4-29-19
1,304,017	Angle Fixing and Transposing Devices	5-20-19
1,311,416	Automatic Plate—Cameras	7-29-19
1,311,447	Camera Mechanism	7-29-19
1,315,307	Film—Supports for Cameras	9-9-19
1,331,978	Methods of and Apparatus for Photographic Cartography	2-24-20
1,485,929	Lenses	3-4-24
1,558,272	Aeroplane Camera	10-20-25
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1,910,425	Methods of Making Maps	5-23-33
1,911,142	Apparatus for Correcting Tilted Photographs	5-23-33

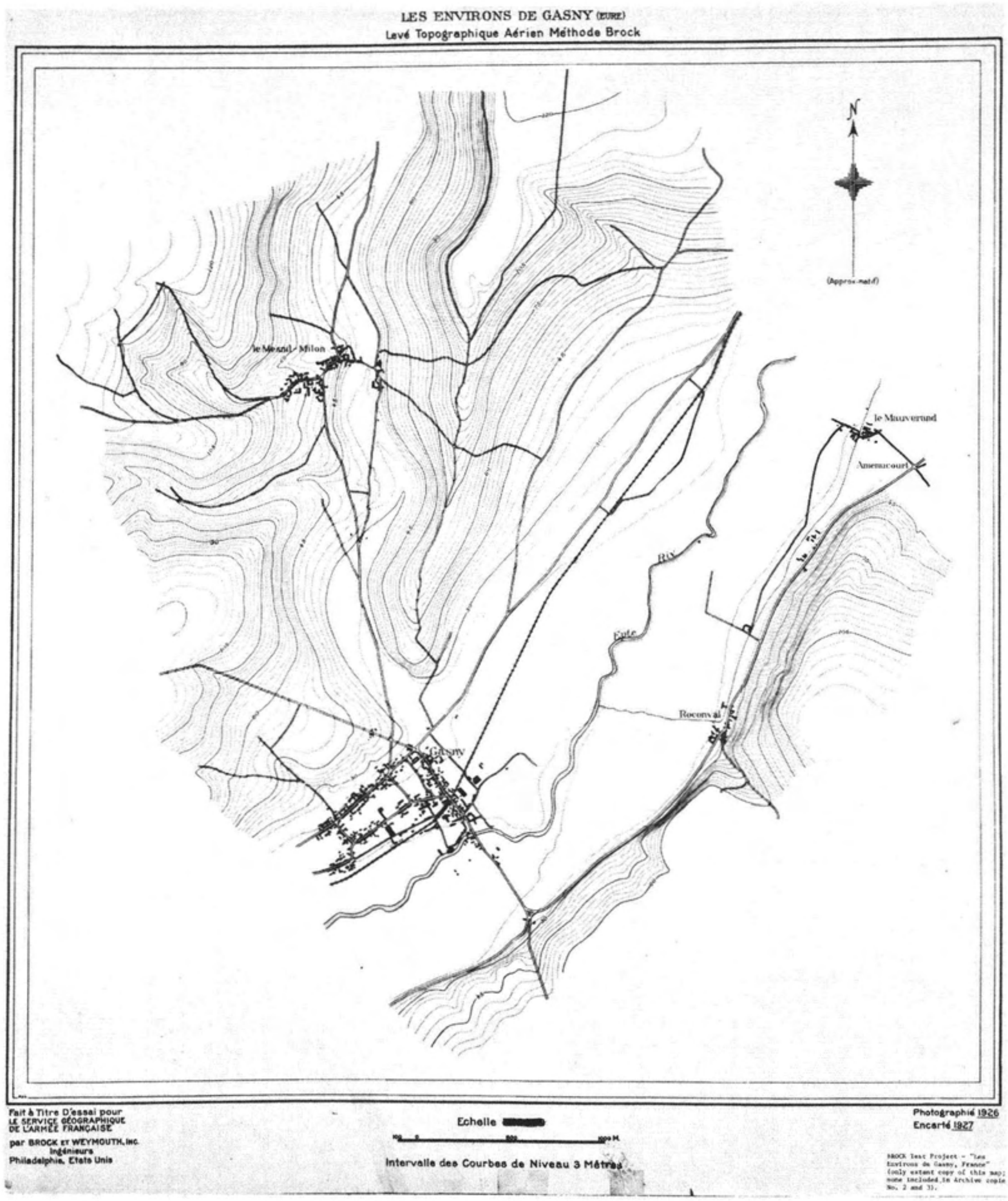

FIG. 14. Brock Process Demonstration Map for the French Army, vicinity of Gasny, France, 1927. Publication scale 1:10,000.

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