8. Katz, Amrom H. "Height Measurements with the Stereoscopic Continuous Strip Camera." PHOTOGRAMMETRIC ENGINEERING, v. XVIII, March 1952.
9. Macdonald, Duncan E. "Image Motion in Air Photography." PHOTOGRAMMETRIC ENGINEERING, v. XVIII, December 1952.
10. McNeil, G. T. "Photogrammetric Analysis of Image Motion Compensation." PHOTOGRAMMETRIC ENGINEERING, v. XVII, September 1952.
11. Kistler, Philip S. "Continuous Strip Aerial Photography." PHOTOGRAMMETRIC ENGINEERING, v. XII, June 1946.
12. Katz, Amrom H. "A Problem at Inch'on." PHOTOGRAMMETRIC ENGINEERING, v. XVII, March 1951.
13. Goddard, George W. "New Developments for Aerial Reconnaissance." PHOTOGRAMMETRIC ENGINEERING, v. XVII, December 1951.
14. Lundahl, A. C. "Underwater Depth Determination by Aerial Photography." PHOTOGRAMMETRIC ENGINEERING, v. XIV, December 1948.
15. Katz, Amrom H. "Air Force Photography." PHOTOGRAMMETRIC ENGINEERING, v. XIV, December 1948.
16. Colwell, R. N. "Aerial Photographic Interpretation of Vegetation for Military Purposes." PHOTOGRAMMETRIC ENGINEERING, v. XIV, December 1948.
17. Corten, F. L. "Survey Navigation and Determination of Camera Orientation Elements." *Photogrammetria*, v. XVI, 1959–1960, No. 4.
18. Helava, U. V. "Mathematical Methods in the Design of Photogrammetric Plotters." *Photogrammetria*, v. XVI, No. 2.
19. Thompson, E. H. "An Exact Linear Solution of the Problem of Absolute Orientation." *Photogrammetria*, v. XV, 1958–1959, No. 4.
20. *Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958.* Bureau of Public Roads, Washington 1958.
21. Moffitt, Francis H. *Photogrammetry.* Internat. Textbook Co., Scranton, Pa., 1959.
22. American Society of Photogrammetry, MANUAL OF PHOTOGRAMMETRY. Banta Publishing Co., Menasha, Wis., 1952.
23. Hallert, Bertil. *Photogrammetry.* McGraw-Hill, 1960.
24. O'Connor, Desmond. "Improved Methods of Ground Control for Photogrammetric Work in Australia." Master's Thesis, University of New South Wales, Sydney, 1959.

*Close-Range Photogrammetry— A Useful Tool in Motion Study**

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AT PRESENT, three basic techniques are being used in industrial methods study. The first and most popular in the United States is the classical "stop-watch and personal observation" means of studying time and motion. Hundreds or even thousands of cycles of a specific working process are sometimes required in the analysis.

The second technique involves the use of high-speed motion pictures. An advantage is that a permanent record of the motion is made which can be reviewed at any time. Nevertheless, this method has failed to gain much popularity because it offers little advantage, with respect to cost, over personal observation.

The cyclegraph or so-called point-light process is the third possibility. This technique has given some aid to industry in analyzing motions and improving methods. Light patterns are made on photographic film in a still camera from lamps attached to an operator's hands or arms. However, a continuous path of light leaves much to be desired in the

* Submitted in the competition for the 1962 Bausch and Lomb Photogrammetric Award.

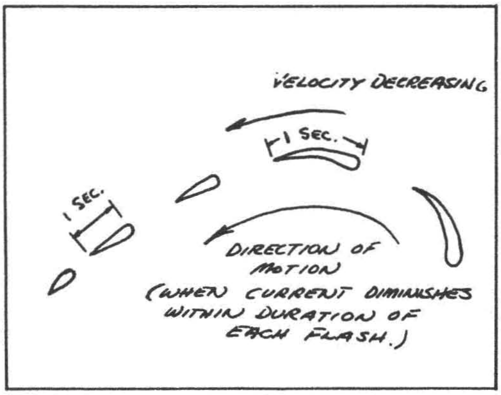

FIG. 1

motion study, the direction and speed of the motion.

These important properties can be recorded on the film by introducing into the system a variable electronic interrupter. This device makes the lights flash on and off at regular intervals and varies the intensity during each flash. It should be noted that in two-dimensional photography the plane of motion must be perpendicular to the camera axis in order for the distance between successive flashes to indicate relative speed of motion. The purpose of the interrupter is illustrated in Figure 1. The cyclegraph system in combination with the interrupter is termed a chronocyclegraph system.

The major common limitation of these three methods of motion study is that, although all offer much in a two-dimensional qualitative sense, none offers the possibility of an accurate quantitative analysis. Actual measurements of critical hand, head, foot, or even body measurements cannot be made because of the missing third dimension, depth.

Photogrammetry, the science of making precise and accurate measurements from photographs, offers the solution and can lend itself to a more scientific technique of motion study. This method would not only give a permanent record of the motions being studied but also would allow accurate measurements to be made in any direction.

Metrical photography had its beginning in France in 1859 with Aimé Laussedat's surveying camera. It has experienced its greatest advance in the United States within the past two decades. Close-range photogrammetry has been used successfully in Europe for more than twenty-five years and is now gaining acceptance in this country.

Today, photogrammetry finds its main use in its original purpose—topographic mapping. While nearly 95 per cent of the nation's mapping program is still accomplished through photogrammetric means, the number of non-geodetic applications of photogrammetry, particularly close-range photogrammetry, is rapidly mounting.

Ballistic investigations and satellite tracking, traffic accident investigations, structural deformation studies, and precise medical measurements, and in addition measurements involved in many other important processes, can be made with a photogrammetric approach. Hence, the relatively new field to the American people has been broadened considerably.

Industrial methods study, as thought of today is the complete analysis of the methods, tools, and materials used in production. Its purpose is to eliminate unnecessary waste of materials and time so that more economical manufacturing methods can be practiced. The great competition involved in industry demands lower production costs of each manufacturer in order that he may avoid losing his business because of lower prices of a competitor.

The answer to lower production costs is not lower wages. Also efficiency in production cannot be assured by "speeding up" of the operators. Industry has found the solution in methods engineering.

The first methods study was conceived in 1885 by Frederick W. Taylor. As a newly appointed foreman at the Midvale Steel Company in Philadelphia, Taylor felt a great responsibility for the output of his department. After much study, he evolved a simple principle that forms the basis for the operation of modern industry. This is that better production is achieved when each man has a definite job to do, in a definite time, and in a definite manner. From this hypothesis has stemmed the present science of methods study.

This study consists of two concepts which are basically integrated and somewhat dependent upon each other; these are time study and motion study. The bulk of the remaining discussion in this paper is concerned with the study of motion and the application of photogrammetric techniques to it.

With the use of proper equipment, photogrammetry could easily become a useful tool to industrial motion study. The author believes that photogrammetric stereopairs, taken of the job being done, could allow much closer attention to detail, the major subject of motion study. The results might

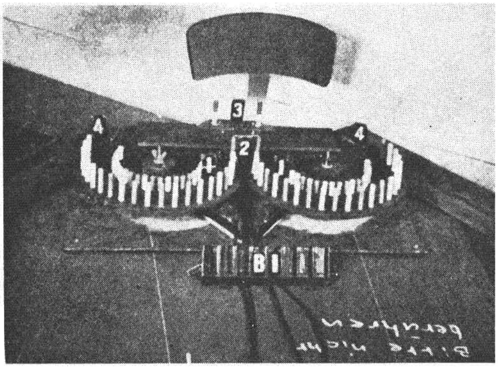

FIG. 2

far transcend any of those achieved by normal analysis.

Some research along this line has been carried on by Dr. M. Zeller at the Industrial Management Institute of the Swiss Federal Institute of Technology in Zurich, Switzerland. A description of Dr. Zeller's research might best explain the equipment and procedure involved in making the motion study.

Dr. Zeller writes of his motion study in a paper appearing in *The International Archives of Photogrammetry*, 1954:

> "For the study of the economy of working processes, an exact knowledge of the spatial curves of the single movements and their strewing, and consequently the possibility of a comparison with other working dispositions is necessary. Only this possibility to compare permits of ascertaining the most favourable working conditions with regard to length of way and form."

A working place in the laboratory at Zurich is seen in Figure 2. As in the chronocyclegraph method, the operator is equipped with small incandescent lamps. In this case,

FIG. 3

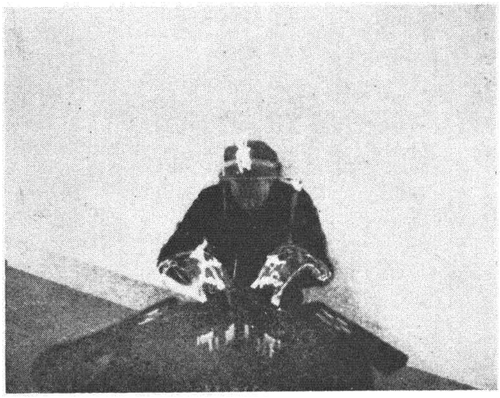

FIG. 4

the head, shoulder, and hand lamps were used as shown in Figure 3. The lamps trace out the motions being made by the operator while he is performing a specific task, and are recorded stereoscopically in a time exposure. Figure 4 shows one-half of a stereopair of pictures taken of the operator's movements.

For his research, Dr. Zeller employed a Wild stereocamera having a basic length of 40 centimeters. In the scale of 1:2, plotting accuracy of about one millimeter is obtained for photographing distances up to four meters. Figures 5 and 6 show the camera and the laboratory setup.

Another available camera is the Zeiss SMK wide-angle stereometric camera which was designed exclusively for close-range photogrammetry.

Early experiments with the above system indicated that best results are obtained when three or four repetitions of the job cycle are shown on one stereopair of pictures. This would enable the determination of a better mean value for the course of movement and a

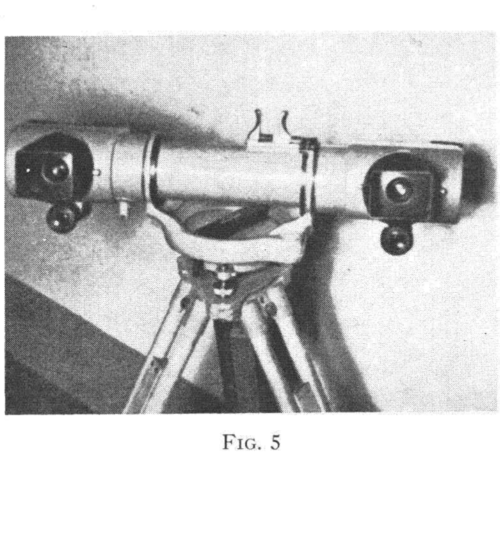

FIG. 5

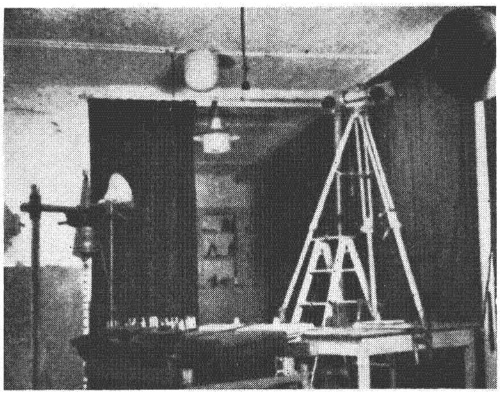

FIG. 6

more reliable picture of the differences occurring between cycles.

To eliminate confusion between independent cycles of the duty being performed, an electronic interrupter with variable intervals is used. The principle and purpose of the automatic interrupter, pictured in Figure 7, are simple. If the current to the lamps is broken periodically, different types of lines can be traced out. Thus, when the lamps are made to flash on for one second and off for one-quarter second, a dashed or broken line results. Cycles can be segregated merely by changing the time interval. Since the movements of one cycle are continually crossing with movements of another, the variable interrupter is a very necessary part of the recording equipment. Of course, the direction and speed of the motion can be obtained, as in the case of the chronocyclegraph. However, absolute, rather than relative velocities can now be found.

The viewing and subsequent plotting of the spatial curves may be executed on any reliable stereoplotter. In his research, Dr. Zeller

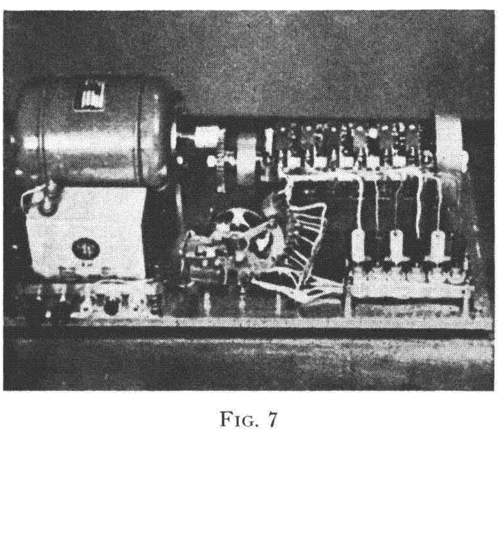

FIG. 7

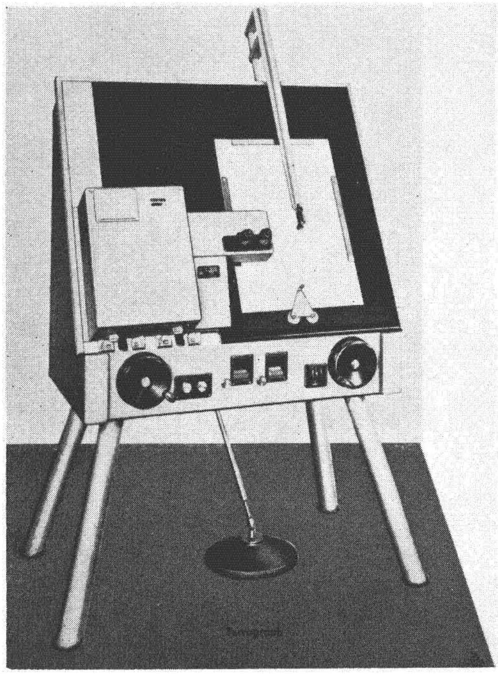

FIG. 8

used a Wild A-4 plotter, but many others are suitable. The Zeiss company offers the Terragraph, shown in Figure 8, an instrument similar to the A-4 in that its operation can be quickly learned by non-photogrammetrists. Typical results of the plotting of one cycle are shown in plan and elevation views in Figure 9.

The author has made a sincere effort to investigate European use of photogrammetric motion study. However, to date little success has come from the investigation. Five photogrammetric equipment manufacturers were contacted in Switzerland, Germany, and Italy; one of these gave references to others allegedly engaged in research on the subject; one supplied a paper by Dr. Zeller on his research; two stated that photogrammetric motion study is unknown to them; one did not reply. An attempt to get Dr. Zeller's personal comments on the subject also failed.

Since so little information has been obtained, it is impossible to make a thorough analysis of the practicability of the method at this time. It should be noted however that a senior Industrial Engineering class at the University of Illinois was introduced to the method through interest arising from the author's work on this paper. After hearing the details involved in photogrammetric motion study and looking over the equipment

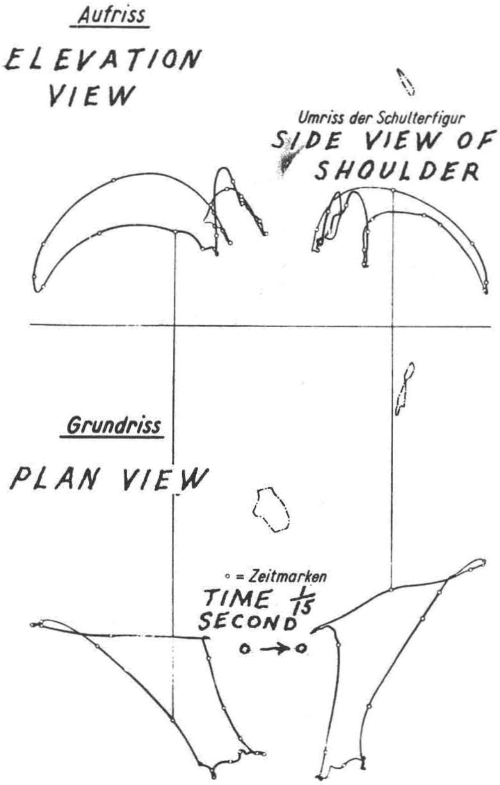

FIG. 9

available at the University, the I. E. class reacted favorably.

One aspect disturbed the class somewhat—that of cost. Like other precision instruments, photogrammetric equipment is very expensive. A combination of the Zeiss SMK stereo-camera and the Terragraph plotter may run to $20,000 or slightly more. However, it remains to be seen if the practicability of the method does not outweigh the disadvantage of initial cost.

There are several alternatives by which equipment cost to the industrial firm might be reduced or even removed as a major disadvantage in photogrammetric motion study:

1. Motion studies could be made on a consulting basis. The consulting engineer would come into a plant which desires a motion study, take the pictures, reduce the raw data on his own plotter, and furnish the plant with the results for the analysis. In this system no equipment cost is involved.
2. A plotting center could be established, to which any firm could send data in the form of pictures. Plotting would be done at the center; thus, equipment cost is lessened by the price of the plotter, or 75 per cent.
3. The method would still be useful if no plotting at all were done. Many motion studies are not concerned with a quantitative analysis. A qualitative analysis would be greatly improved by the mere addition of the third dimension. Viewing could be done on a simple stereoscope of negligible price.

The only way to determining the usefulness of the method is to work with it—to conduct research wherever facilities permit. Research is the very backbone of engineering and may someday prove photogrammetry to be a useful tool in the industrial world.

*Ultra-Wide-Angle Mapping**

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(*Abstract is on next page*)

NOMENCLATURE for angular coverage of mapping camera lenses has been backed into a corner from which there appears to be no escape. The photogrammetric world is stymied. Some old timers are still around who mapped with normal-angle photography when wide-angle lenses first became available. Now ultra-wide-angle has been added to the group. However, normal-angle photography is not normal, and wide-angle is not

* Presented at the 28th Annual Meeting of the Society, The Shoreham Hotel, Washington, D. C., March 14–17, 1962.