Motion study and time study instruments of precision / by Frank B. Gilbreth and Lillian Moller Gilbreth.

MOTION STUDY AND TIME STUDY INSTRUMENTS OF PRECISION.

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The greatest waste in the world comes from needless, ill-directed, and ineffective motions. These motions are unnecessary and preventable. Their existence in the past was excusable, because there was no knowledge of how to dispense with them. That excuse no longer obtains. The methods and devices of waste elimination are known and are being constantly used. But the knowledge of how to make these great world-wide economies is being disseminated at an astonishingly slow speed.

This paper is for the purpose of disseminating such knowledge, particularly as to the devices that are used for making the measurements that enable us to eliminate waste.

In the science of management, as in all other sciences, progress that is to be definite and lasting depends upon the accuracy of the measurements that are made. There are three elements to every measurement:

1. The unit measured.
2. The method of measurement.
3. The device by which the measurement is made.

It is here our aim to show the development of the devices of measurement, that is, of instruments of precision that apply to one branch of the new type of management, namely, to motion study and its related time study.

The fundamental idea of the new type of management that has been variously called "Scientific Management", or "Measured Functional Management", is that it is based upon the results of accurate measurement. This fundamental idea has

been derived as follows: Each operation to be studied is analyzed into the most elementary units possible. These units are accurately measured, and, as the results of the measurement, the efficient units only are combined into a new method of performing the work that is worthy to become a standard.

Dr. Taylor, the great pioneer in time study, and his coworker, Mr. S. E. Thompson, have clearly defined their conception of time study as "the process of analyzing an operation into its elementary operations, and observing the time required to perform them". Time study has to do, then, fundamentally, with the measurement of units.

Now motion study has to do with the selection, invention, and substitution of the motions and their variables that are to be measured. Both accurate time study and motion study require instruments of precision that will record mechanically, with the least possible interference from the human element, in permanent form, exactly what motions and results occur. For permanent use the records must be so definite, distinct, and simple that they may be easily and immediately used, and lose none of their value or helpfulness when old, forgotten, or not personally experienced by their user.

There have undoubtedly been some vague motion studies and guess-work time studies made as far back as historical records are available, particularly in the arts of warfare. The importance of rhythm, for example, which is one of the fundamentals in motion study, was recognized in the Assyrian and Babylonian pictorial records which perpetuate the methods of their best managers, as examination of photographs of such records in our possession will plainly show. Babbage, Coulomb, Adam Smith,—all recognized the importance of the time element in industrial operations, for the purpose of obtaining methods of greatest output, but not methods of least waste. It was not, however, until Dr. Taylor suggested timing the work periods separately from the rest periods that the managers tried to find accurate time-measuring devices.

It is not always recognized that some preliminary motion study and time study can be done without the aid of any accurate devices. It is even less often recognized that such work, when most successful, is usually done by one thoroughly conversant

with, and skilled in, the use of the most accurate devices. In other words, it is usually advisable in studying an operation to make all possible improvements in the motions used and to comply broadly with the laws of motion study before recording the operation, except for the preliminary record that serves to show the state of the art from which the investigation started. However, in order to make a great and lasting success of this work, one must have studied motions and measured them until his eye can follow paths of motions and judge lengths of motions, and his timing sense, aided by silent rhythmic counting, can estimate times of motions with surprising accuracy. Sight, hearing, touch, and kinesthetic sensations must all be keenly developed. With this training and equipment, a motion- and time-study expert can obtain preliminary results without devices, that, to the untrained or the uninformed, seem little short of astounding. When the operation has received its preliminary revision and is ready for the accurate measurements that lead to actual standardization and the teaching that follows, devices of precise measurement become imperative for methods of least waste that will stand the test of time.

Early workers in time study made use of such well-known devices as the clock, the watch, the stop-watch, and various types of stop-watches attached to a specially constructed board or imitation book. Through the use of these it became possible to record short intervals of time, subject, of course, always to the personal error. The objection to the use of these methods and devices is their variation from accuracy, due to the human element. This is especially true of the use of the stop-watch, where the reaction time of the observer is an element constantly affecting the accuracy of the records. But the greatest loss and defect of personally observed and recorded times is that they do not show the attending conditions of the varying surroundings, equipment and tools that cause the differences in the time records, and give no clue to causes of shortest or quickest times.

As for motion study, Marey, with no thought of motion study in our present use of the term in his mind, developed, as one line of his multitudinous activities, a method of recording paths of motions, but never succeeded in his effort to record direction of motions photographically.

Being unable to find any devices anywhere such as the work of our motion study required, the problem that presented itself, then, to us who needed and desired instruments of precision, applicable to our motion study and to our time study, was to invent, design and construct devices that would overcome lacks in the early and existing methods. It was necessary to dispense with the human element and its attending errors and limitations. We needed devices to record the direction as well as the path or orbits of motions, and to reduce the cost of obtaining all time study and motion study data. These were needed not only from the scientific standpoint, but also from the standpoint of obtaining full co-operation of the mechanics and other workers. Many of these had, as a class, become suspicious of time study taken secretly by those who, they thought, did not know enough about the practical features of the trade to take the time study properly, and could not prove that the times were right after putting them on paper. Here was absolute pioneer work to be done in inventing devices that would record times, paths, and directions of motions simultaneously. With the older time study devices there was no way of recording accurately either the unit timed or the controlling surrounding conditions. The "elementary units" were groups of motions. They were elementary only with relation to the stop-watch, with which it is impossible to record accurately the time of an element of a motion, since it takes two decisions and two motions to press the stop-watch. These "groups of motions" were sometimes described at greater or less length, the accuracy of the description depending upon the power of observation of the recorder and the detail with which the time at his disposal, his willingness and his ability to observe, permitted him to set down his observations.

Through our earliest work in making progress records we recognized the necessity of recording time and conditions accurately and simultaneously, the records being made by dated photographs. This method was particularly applicable in construction work,* where progress pictures taken at frequent intervals present accurate records of the surroundings, equipment and tools that affect records of output of various stages of development.

* See "Concrete System", Engineering News Publishing Co., N. Y.

In making more intensive studies of certain trades, such as shoveling, concrete work, and bricklaying, we found it advantageous to photograph the various positions in which the hands, arms, feet, and other parts of the body involved in the operations were placed, and to record the time taken in moving from one position to another by one method, as related to the time taken in moving from the same first to the same second position by another method.† Our intensive study of bricklaying, which grew out of an appreciation of the unique history, present practice and doubtful future of this trade, led us to a more intensive study of the problems of motion and time study in general.‡ Bricklaying will always be the most interesting of all examples to us, for the reason, among others, that it was the first trade to use the principle of duplicate, interchangeable parts system of construction; had had six thousand years of practice in all countries; and was, therefore, a comparatively finished art, but not a science, when we undertook to change it by means of motion study.

Fortunately, we are now able to use the motion picture camera with our speed clock, and other accessories, as a device for recording elements of motions and their corresponding times, simultaneously. Our latest microchronometer records intervals of time down to any degree of accuracy required. We have made, and used, in our work of motion study investigations of hospital practice and surgery, one that records times to the millionth of an hour. This is designed for extremely accurate work, but can be adjusted to intervals of any length desired, as proves most economical or desirable for the type of work to be investigated.

Having completed our microchronometer, we proceeded as follows: The microchronometer was placed in the photographic field near the operator and his working equipment, and against a cross-sectioned background or in a cross-sectioned field, and at a cross-sectioned work bench or table. The operator then performed the operation according to the prescribed method, while the motion-picture camera recorded the various stages of the operation and the position of the hand on the microchronometer, simultaneously. Thus, on the motion picture film we obtain in-

† See "Motion Study", D. Van Nostrand Co., New York City.

‡ See "Bricklaying System", Myron C. Clark Publishing Co., Chicago.

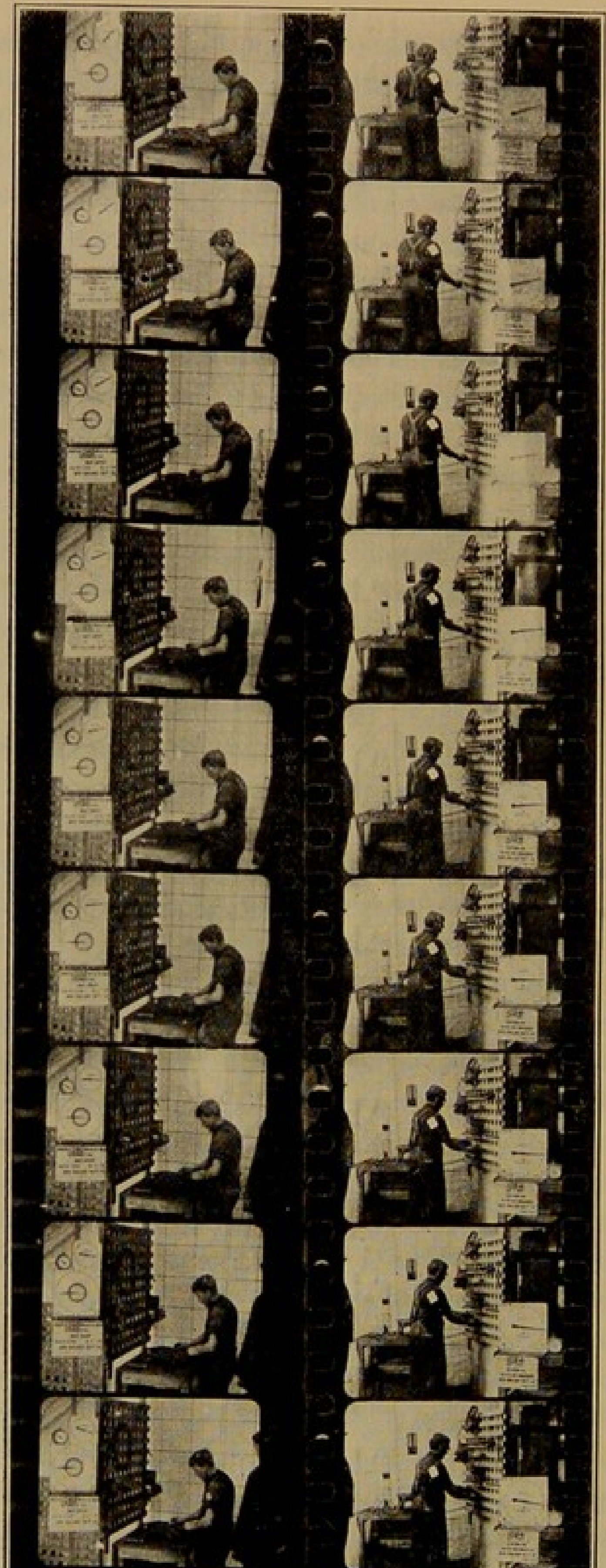

Fig. 1. Fig. 2.

Micromotion Studies of Assembly. Note the microchronometer, also the cross-sectioned assembly packet and the specially constructed assembly table.

termittent records of the paths, the lengths, the directions, and the speeds of the motions, or the times accompanying the motions, these records all being simultaneous; and the details of the conditions of the surroundings that are visable to the eye are recorded without the failings of memory. This was a distinct step in advance, but we realized that there was a lack in the records. It was difficult, even for one especially trained and experienced, to visualize the exact path of a motion, and it was not possible to measure the length with precision from the observations of the motion picture film alone, as there is no summary or recapitulation of all the motions of a cycle or operation in any one picture. To overcome this lack we invented the cyclegraph method of recording motions. This consists of attaching a small electric light to the hand or other moving part of the person or machine under observation. The motion is recorded on an ordinary photographic film or plate. Upon observing our very first cyclegraph records, we found that we had attained our desire, and that the accurate path taken by the motion stood before us in two dimensions. By taking the photographic record stereoscopically, we were able to see this path in three dimensions, and to obtain what we have called the stereocyclegraph. This showed us the path of the motion in all three dimensions; that is, length, breadth, and depth. It did not, however, contain the time element. This time element is of great importance not only for comparative or "relative" time, but also for exact times. This time element is obtained by putting an interrupter in the light circuit, that causes the light to flash at an even rate at a known number of times per second. This gives a line of time spots in the picture instead of a continuous cyclegraph light line. Counting the light spots tells the time consumed.

The next step was to show the direction of the motions. To do this it was necessary to find the right combination of volts and amperes for the light circuit and the thickness of filament for the lamp, to cause quick lighting and slow extinguishing of the lamp. This right combination makes the light spots pointed on their latest, or forward, ends. The points, thus, like the usual symbol of arrow heads, show the direction. The result was, then, of course, finally, stereochronocyclegraphs showing direction. These act not only as accurate records of the motions and

times, but also serve as admirable teaching devices. Wire models of cyclegraphs and chronocyclegraphs of the paths and the times of motions are now constructed that have a practical educational value besides their importance as scientific records. These

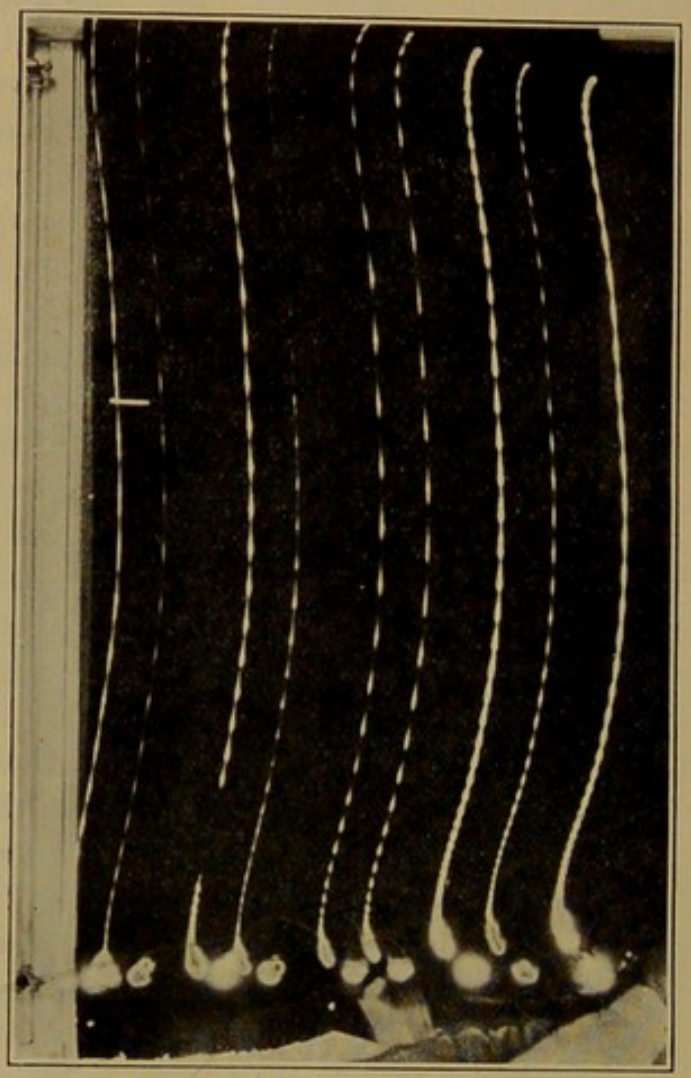

Fig. 3. Typical Cyclegraph Light Lines. Note the possibilities of differentiating various motion paths from one another.

models are particularly useful as a step in teaching visualization of paths by photographs alone, later.

Our latest apparatus in the field of recording devices apparently fulfills all present requirements of the time- and motion-study experts and their assistants and the teachers who are now devoting their lives to the transference of skill and experience from those who have it to those who have not.*

* See "Primer of Scientific Management", D. Van Nostrand Co., N. Y.

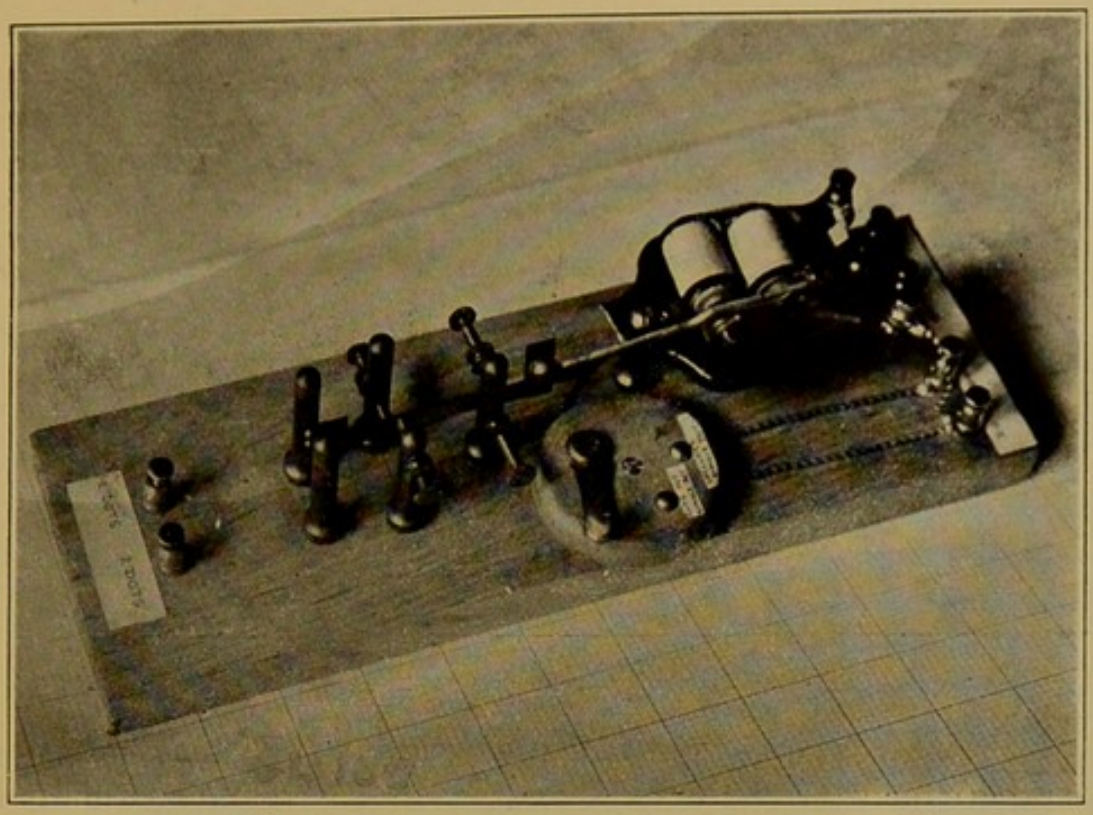

Fig. 4. Type of Chronocyclegraph Apparatus.

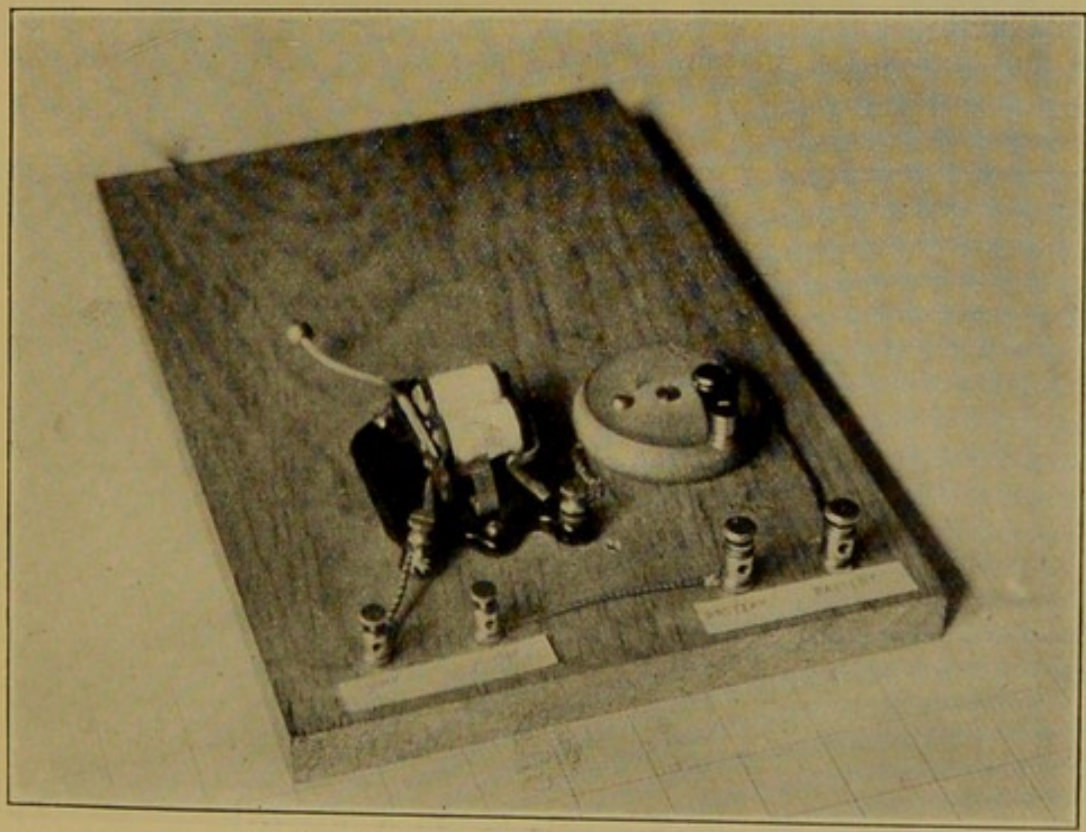

Fig. 5. Type of Chronocyclegraph Apparatus.

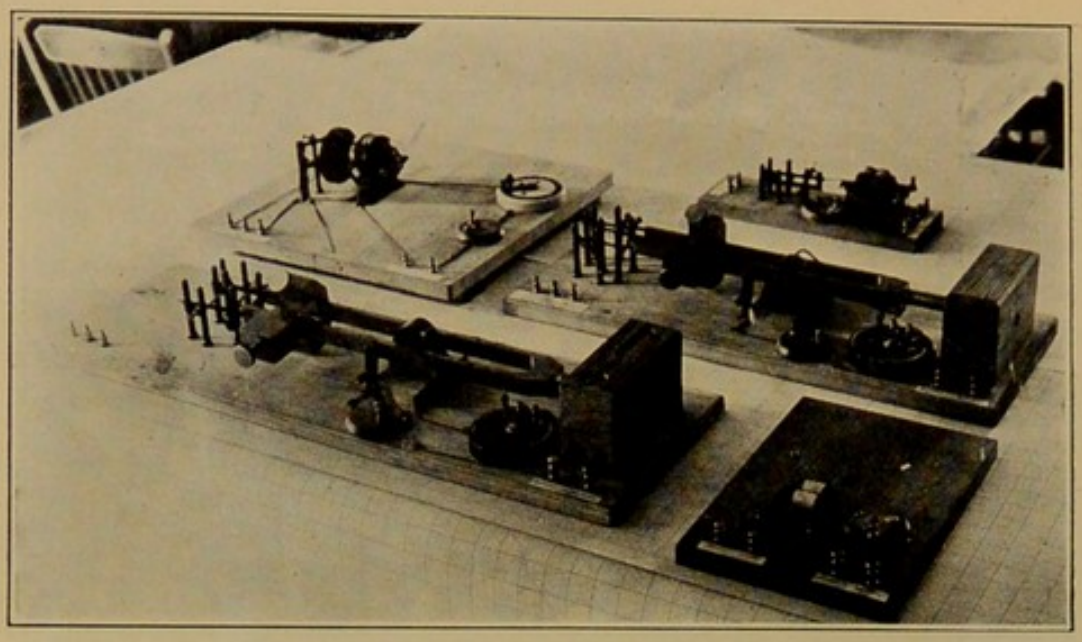

Fig. 6. Type of Chronocyclegraph Apparatus.

We have also devised and used many special kinds of apparatus; for example, devices for recording absolute continuity of motion paths and times, doing away with the slight gaps in the record that occur between one picture and the next on the cinematograph film, due to the interval of time when the film is moving, to get in place for the next exposure. To overcome this objection we have a double cinematograph, that one part

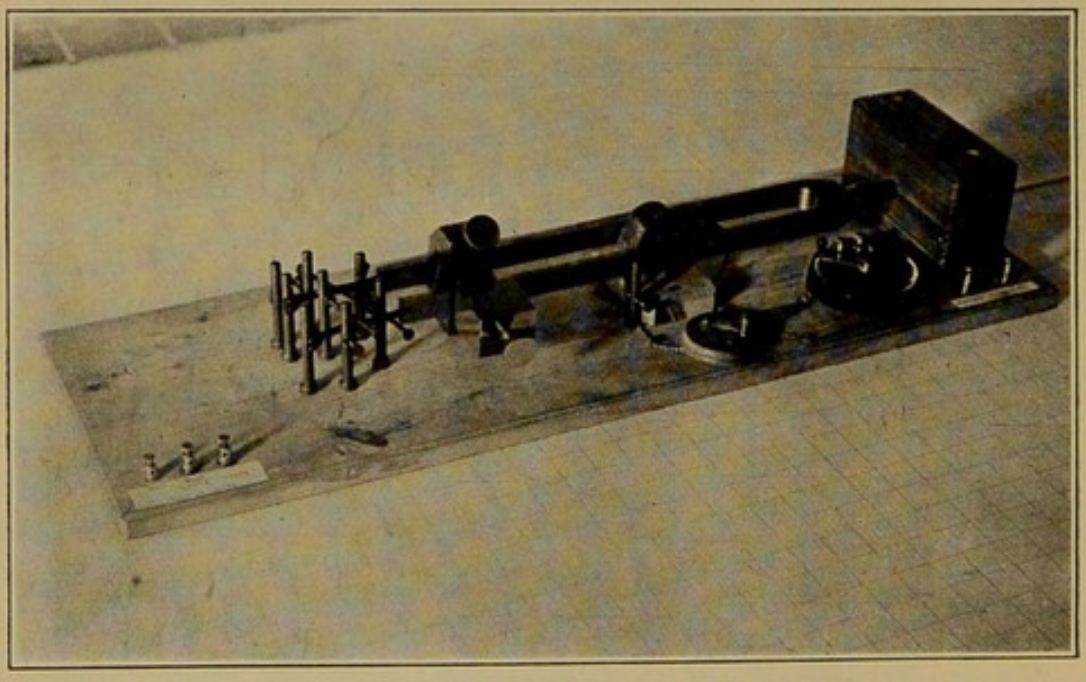

Fig. 7. Type of Chronocyclegraph Apparatus.

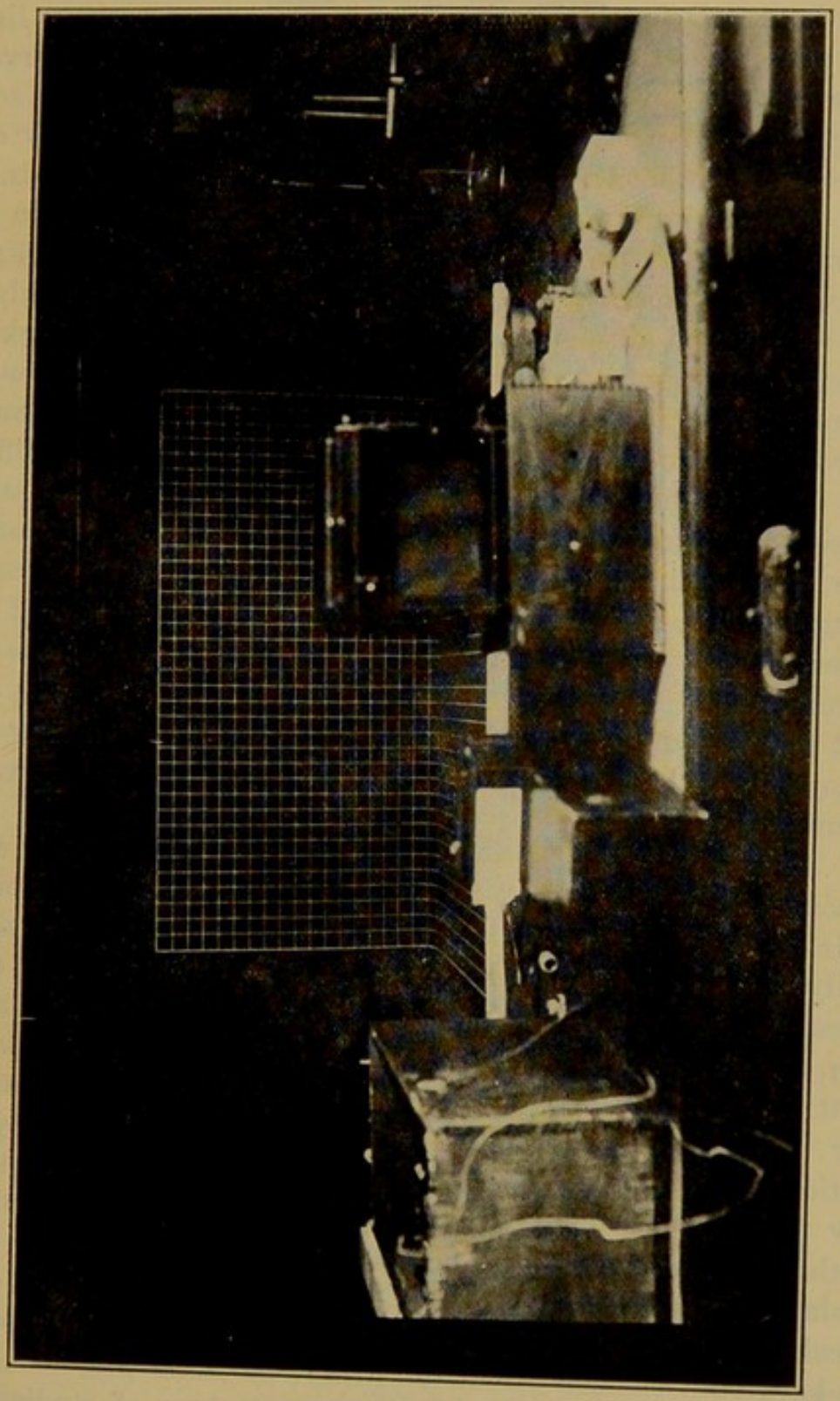

Fig. 8. Type of Chronocyclegraph Apparatus.

may record while the other moves from one exposure to the next. In this way we get a continuous record of the operation. There have been occasional objections to all methods of making time and motion studies that involve the presence of an observer. Some of these have come from those working on what they consider their own secret processes, who object to having any observer record what they are doing, believing that the time study man is obtaining knowledge of their skill and giving them no information in return. Others have come from those who have seen or heard "secret time study" and "watch-book time study", and who regard all observers as spies because of general lack of understanding and co-operation; and there are some instances where they are right. For such cases we have designed an auto-micromotion study, which consists of an instantaneous modification of the standard micromotion apparatus, and also the auto-stereochronocyclegraph apparatus. This enables the operator to take accurate time study of himself. He can start the apparatus going and stop it from where he works, with one motion of his finger or his foot. This invention supplies every possible requirement and feature for time and motion study processes, except the help and advice of a properly qualified observer, or the annoyance of having one not fitted by training, experience, or natural qualities to coöperate.

There is not space in this paper for a discussion of the educational features of observations made with these devices, or of their influence upon the new and much needed science of fatigue study, or of their general psychological significance.* It is only necessary to emphasize their adaptability, flexibility, and relation to economy. We have here a complete set of inexpensive, light, durable apparatus, adaptable to any type of work and to any type of observer or self-observation. It consists of systematically assembled units that may be so combined as to meet any possible working condition. Through a specially devised method of using the same motion picture film over and over again, up to sixteen times, and through a careful study of electrical equipment and of various types of time spot interrupters, we have been enabled to cut down the cost of making time and motion study, until now the most accurate type of studies, in-

* See "Fatigue Study", Sturgis & Walton, N. Y.

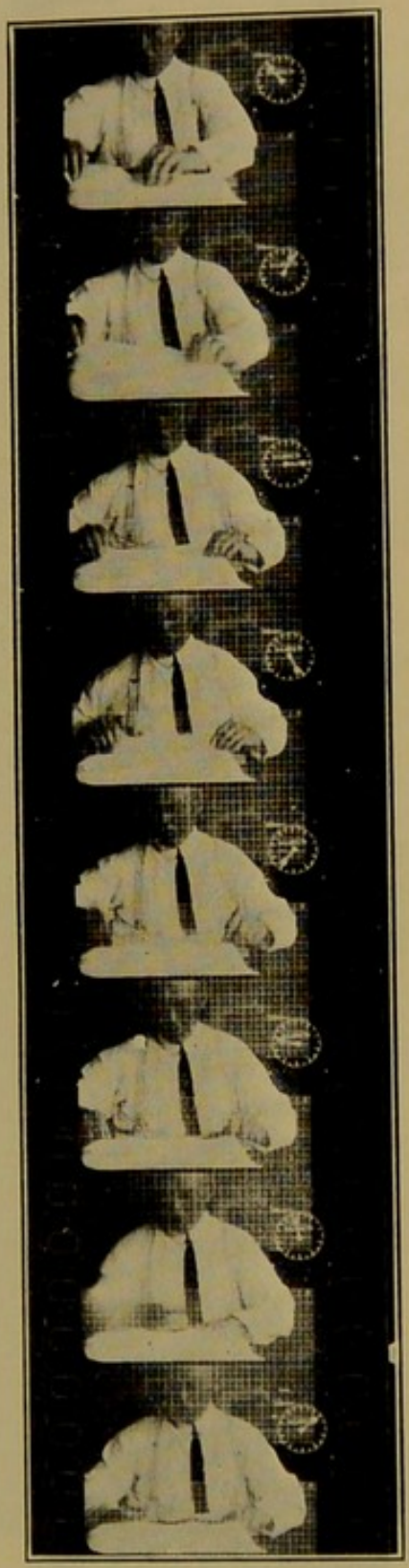

Fig. 9. Automatic Motion Study with Vertical Penetrating Screen in the Plane of the Motions.

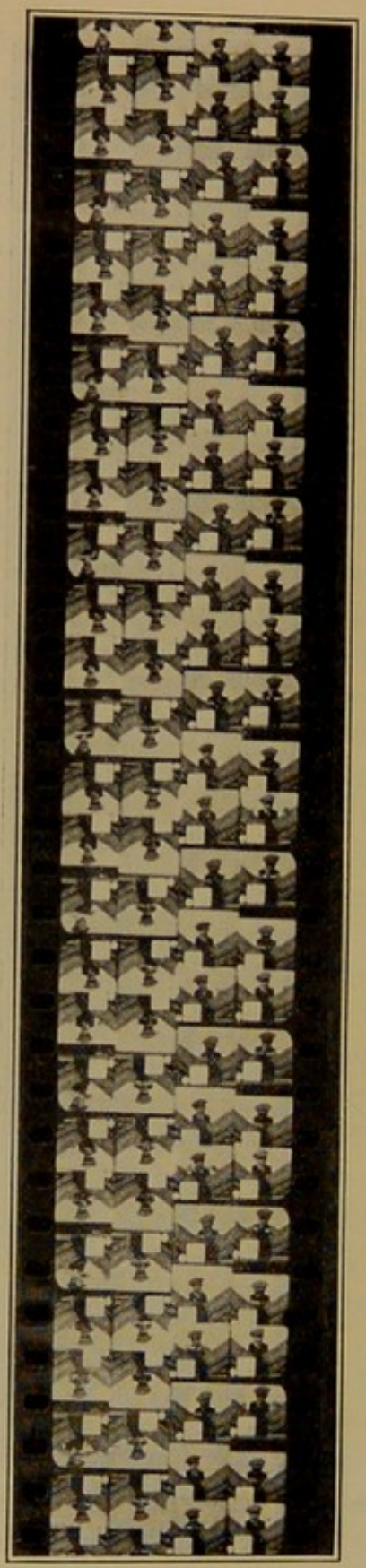

Fig. 10. Micro motion studies recorded on film, a device for reducing cost while retaining accuracy and permanence of the detailed record.

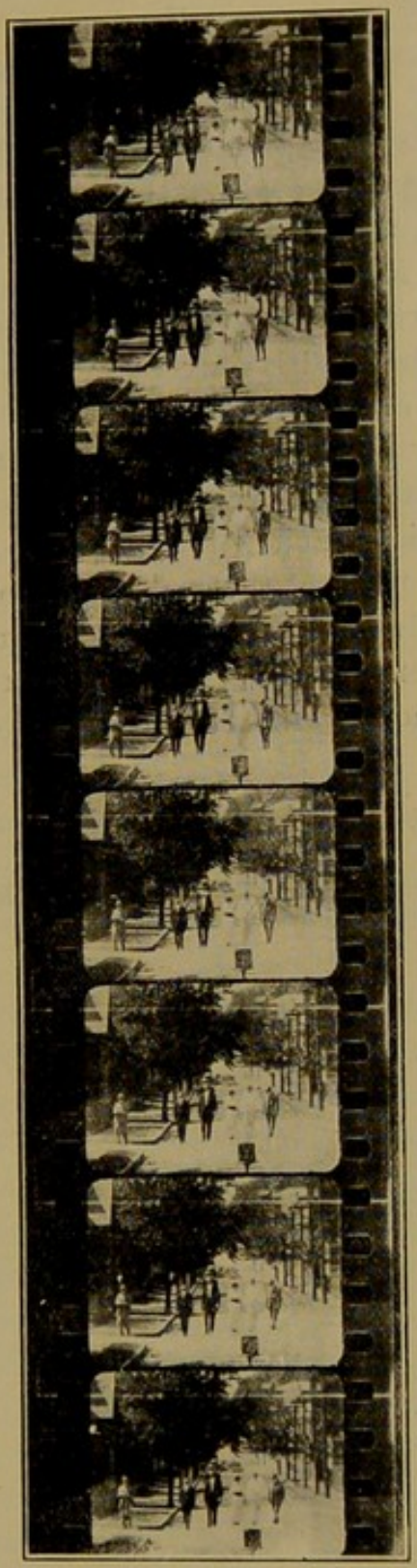

Fig. 11. Autotele Time Study for Recording Motions at a Great Distance and the Position of the Finger of the Microchronometer Less Than Thirty Feet Away.

volving no human equation in the record, can be made at less cost than the far less accurate stop-watch study. This time study and motion study data can be used when it is "cold". No specially gifted observer, combined with the most willing and efficient recorder, can compete with it for observing and recording facts. It does not depend upon a human memory to "give up" its facts. It is usable at any time and forever, after it is once taken. Naturally, the requirements for refinement and the special set-ups to be used in any case must be determined after some study of the case in hand.

There are now available, therefore, instruments of precision fitted to make measurements as fine as the most exact science demands,—economical enough to make both immediate and ultimate savings, and that meet the demands of the most exacting industrial progressive. When the time and motion study is taken with such instruments of precision, there are still other by-products that are of more value than the entire cost of the time and motion studies.*

* See "Time Study; a Factor in the Science of Obtaining Methods of Least Waste".

See "Psychology of Management", Sturgis & Walton, N. Y.