

3 8006 10058 6349



REPORT NO. 86.

DECEMBER, 1954.

THE COLLEGE OF AERONAUTICS

C R A N F I E L D

The Application of Memo-Motion to Industrial Operations

-by-

Clifford J. Norbury

----

SUMMARY

Memo-Motion, or Spaced Shot Photography, was introduced as a tool of Work Study by Dr. Mundel, then of Purdue University, in 1946, as a means of reducing the cost of film analysis on long operations by using a camera driven by a geared down electric motor, giving exposures every second. Since its introduction Memo-Motion has been applied to a limited extent in the U.S.A., but it is not known to be in use at all in England.

The object of this thesis was to investigate the field of application of Memo-Motion Study, and to extend its use into new fields by developing apparatus that could take photographs at intervals varying from two per second to one every four hours.

Experimental work has shown that Memo-Motion has the following applications in which it has special advantages over other forms of study.

- 1) Single Operator Repetition Work, for which the term Macro-Motion study has been introduced here.
- 2) Area Studies, the study of a group of men or machines.
- 3) Team Studies.
- 4) Utilisation Studies.
- 5) Work Measurement.

The main conclusion is that Memo-Motion could become a valuable new tool of Work Study, and can be used where other forms of study would be impractical or uneconomic. It is a very versatile tool, and the addition of a Spaced Shot attachment to a cine-camera greatly extends its industrial application.

MEP

CONTENTS

<u>Section</u>	<u>Page</u>
1. <u>Summary</u>	1
2. <u>Acknowledgements</u>	4
Part I. 3. <u>Introduction</u>	4
3.1. Historical Note	4
3.2. Scope of the Research into Memo-Motion	5
4. <u>The Field of Application of Memo-Motion Study</u>	5
5. <u>Conclusions and Comments</u>	7
5.1. The Advantages and Limitations of Memo-Motion Study	8
5.2. General Conclusions based on the results of Experimental Studies	11
5.3. Recommendations for Future Work	11
Part II. 6. <u>The Technique of Making Memo-Motion Studies</u>	12
7. <u>The Use of Memo-Motion in Micromotion Studies</u>	15
7.1. Tests to Determine the Application of Memo-Motion Equipment to Micromotion Studies	16
7.2. A Macromotion Study on the Assembly of a Spray Gun	19
7.3. The Analysis of Macromotion Films	19
7.3.1. Macromotion Therbligs	20
7.3.2. Preliminary Analysis	21
7.3.3. Construction of Sino-Charts	22
7.3.4. Analysis of the Sino-Chart	22
7.3.5. Analysis of the Film for Bad Movements	24
8. <u>The Application of Memo-Motion to Area Studies</u>	24
8.1. The Information obtainable from Area Studies	25

<u>Section</u>	<u>Page</u>
8.2. The Analysis of Area Study Films	26
8.2.1. Analysis of Film on Aircraft Aileron Assembly	27
8.2.2. Analysis of Film of Aircraft Tailplane Assembly	30
8.2.3. Analysis of Film on Aircraft Wing Assembly	32
8.2.4. Analysis of Film on Roller Bearing Wrapping	35
8.3. Short Tests on Area Studies	39
9. <u>The Application of Memo-Motion to Team Studies</u>	40
9.1. The Analysis of Team Study Films	41
9.2. A Team Study in a Steel Mill	41
9.2.1. Analysis of Team Charts	42
9.2.2. Development of a New Method	43
10. <u>The Application of Memo-Motion to Utilisation       Studies</u>	43
11. <u>The Application of Memo-Motion to Work Measurement</u>	45
12. <u>Bibliography</u>	46
<u>APPENDIX I</u>	
A.1. <u>Description of Equipment Used during the Research</u>	47
A.1.1. The Equipment used for producing Memo- Motion Films	47
A.1.1.1. The Modified Bolex H.16 Camera	47
A.1.1.2. The Timing Mechanism.	48

## 2. Acknowledgements

The author wishes to place on record his appreciation of the help and advice given during the writing of this thesis, by many organisations and individuals outside the College of Aeronautics amongst whom are Professor M.E. Mandel, Marquette University, and Robert Lee Morrow, Connecticut.

The assistance and advice given by the staff and employees of the College of Aeronautics, particularly in relation to the construction of the Memo-Motion Apparatus, is also greatly appreciated. The thesis was prepared under the guidance of Mr. H.C. Wiltshire.

## 3. Introduction

Memo-Motion is the technical term describing a specialised branch of photography applied to Work Study, that of taking photographs at fixed intervals, to record information about an operation or process. A 16 mm. cine camera is most often used, with some form of modification or attachment to produce spaced shots.

Memo-Motion is a comparatively recent innovation, being first applied in America during 1946. Since then it has been used to a limited degree in the U.S.A., but very little is known about its use in England. In order to ascertain the field of application of Memo-Motion, it was necessary to carry out practical work in the field and develop apparatus for this purpose.

### 3.1. Historical Note

The cine-camera has, since its invention, been used as a tool in Work Study, especially by Gilbreth. With the continued development of both the techniques of Work Study, and the performance and reliability of motion picture equipment, cine-photography has established itself among the procedures used by Method Study Engineers.

In the rigorous procedure developed for the application of Work Study, the first major step is to record the facts of existing methods, and it is to this function that the cine camera has been applied. The camera is a very efficient means of recording facts which permits detailed study at leisure some time after the actual recording. However, the cine camera has never become a universally used tool, in spite of its advantages. There are many reasons for this, mainly concerned with the limited field in which it can be economically applied.

In 1945 Dr. M.E. Mandel, then of Purdue University, was



approached by the 'Life' magazine to write an article dealing with methods of improving housework, with emphasis on meals produced in the kitchen. In order to cover the one hundred meals the magazine wished to study, 120,000 feet of film would have been required at the normal filming speed of 16 frames per second. This would have cost far more than 'Life' were prepared to pay, and so Mundel developed the technique of Memo-Motion, using a film speed of one frame per second, thus reducing the film cost to one sixteenth of that for normal filming.

Since this new technique was introduced its application has spread to some extent in the country of its origin, but it has hardly developed, for the original film speed of one frame per second has been adhered to, although the Bell and Howell Company of Chicago, have recently marketed a Time Lapse camera with a speed of one frame every eight seconds.

Little printed information about Memo Motion has been produced, but Dr. Mundel, in his book 'Motion and Time Study', gives examples of its application to a foundry and maid service in a hotel.

### 3.2. The Scope of the Research into Memo-Motion

There were, when this work was commenced in October 1953, no cameras suitable for Memo-Motion Study available in England, and hence the first requirement for research was the development of equipment. The basic requirements of the equipment were flexibility and practicability; flexibility because of the necessity to explore many fields, and practicability because if the work was to be of value to industry it had to be of a practical nature.

It was therefore decided to develop equipment based on an existing cine-camera of a type likely to be found in use in industry, and to drive it by impulses of varying frequency from a timing mechanism. It should be stated here that it was considered that the approach of earlier constructors of Memo-Motion apparatus, that of gearing down a synchronous electric motor to drive the camera, was basically wrong, because of its weight and mechanical complexity, and the difficulty of obtaining variable frame intervals.

Having developed the apparatus the object of the research was to find where and how it could be applied, its advantages and limitations, and its future as a tool of Work Study Engineers.

## 4. The Field of Application of Memo-Motion Study

The experimental work performed to obtain information for this thesis has shown that it is difficult to define exactly the extent to which Memo-Motion study may be applied to industry,

for it appears that the field of application is very wide.

One great advantage in the use of Memo-Motion lies in its ability to record simultaneously a wide variety of information. This often makes it unnecessary to define exactly those parts of an operation to be studied before actually making the study, whereas when performing a study by observer and stopwatch, it is essential to decide upon an exact procedure in advance.

This is of importance because it often occurs that the exact nature of a problem is not known before the operation is studied. An example of this occurred at a factory described later in the report. Here it was known that faults existed in the Wrapping Department, but the precise nature of the faults were not obvious before the study was performed. It was thought that the department was over-staffed, but it may have been a materials handling problem, or the lack of an efficient wrapping process, or even a fault in the supervision of the staff. To investigate each of these possibilities separately by observers would have been very costly and time consuming, but the Memo-Motion camera was able to investigate them all at the same time.

It can be used in such widely differing applications as the study of single operators on repetition work, using film speeds of two frames per second, to the study of men and machine utilisation in a large shop, using perhaps 200 frames per day.

There is no doubt that the field of application of Memo-Motion Study has been greatly increased by producing equipment that can take shots at widely differing intervals, and that the use of half-second intervals will displace Micromotion Study on many operations having a cycle of above one or two minutes.

For convenience of definition and discussion, the fields in which Memo-Motion Study can be applied with advantage have been grouped together under the following general headings.

- 1) Single Operator Repetition Work, formerly the field in which Micro-Motion Study was used as a recording medium. Memo-Motion Study can be used on cycles above half a minute and has particular advantages when the cycle exceeds four minutes, the maximum time 100 feet of film lasts at 16 frames per second.
- 2) Area Studies. The study of a group of men, or machines, or both, working in an area which can be covered by the camera.
- 3) Team Studies. This is really a special case of Area Studies, but it is sufficiently important to warrant discussion under a separate heading.

- 4) Utilisation Studies. The evaluation of the utilisation of men or machines, either by long regular interval shots, or randomised shots.
- 5) Work Measurement. Setting up time standards for jobs, or compilation of Synthetic Time Data. Determination of Contingency or Process Allowances.

In addition to application under these general headings, Memo-Motion Equipment could be applied to any recording of long operations, or instrument reading, and would also be a useful piece of research equipment, but these applications fall outside the scope of this thesis.

Each of the fields of application will be discussed fully in separate sections of the thesis, with information on the facts obtainable from the film and the method of analysing them.

## 5. Conclusions and Comments

All the tools used by Work Study Engineers have some applications to which they are suited, and others in which they are useless. The engineer must select the best of them for the specific job in hand. These remarks apply to Memo-Motion equipment just as they do to any other tool, and so it is necessary to discuss critically the results of the experimental work into Memo-Motion Study.

Firstly the exact function of the camera should be clarified. It is solely a recording instrument, giving an instantaneous record of everything within its field of view. It cannot think, or give particular attention to a single item, and neither can it see round corners or sweep a wide area with a glance. A single picture records the situation at the instant it was taken, and hence does not record movements, but by taking another photograph after a short interval of time, movements may be appreciated by comparing the two instantaneous pictures.

This description of a camera may appear trivial, but from it come the limitations regarding the use of photographic techniques as a universal tool of Work Study Engineers. The camera can only give information on what happened at a given time, it can not indicate why it happened, or how it could have been done better; these factors have to be decided by the engineer who analyses the film.

It is necessary for the film to be analysed by someone familiar with the job, in any but the simplest operations. The area which the camera can cover at one setting limits the size of shop that can be studied, and the small film used, 16mm, limits the amount of detail that can be recorded.

The inability of the camera to see round corners often makes it impossible to set the camera where it can see the whole of the operation to be studied. An example of this occurred in an aircraft factory, where it was required to study the operation of a rubber press, with men working on both sides of the machine. The camera could not be placed so that it covered both sides of the press, so without two cameras synchronised together the study was impossible.

The necessity to consider more than one frame of film to study movement means that if the interval between frames becomes too long it will not be possible to correlate the information shown on them as belonging to the same motion. The limiting interval will depend on the type of operation studied, but hand and arm movements are lost when the interval exceeds one second.\*

#### 5.1. The Advantages and Limitations of Memo-Motion Study

Memo-Motion photography offers most of the advantages of normal cine-photography, plus several others peculiar to it; those common to continuous and spaced shot photography will be discussed first. They are.-

- 1) Films produce a more accurate time record than can be achieved by other means, e.g. a stopwatch.
- 2) Films record accurately the sequence of rapid operations, either for analysis, or for future reference on the method used for a particular operation, or for the instruction of personnel.
- 3) The use of filming enables analysis to be performed conveniently away from the job, if necessary by skilled observers who could not be spared for the lengthy process of analysis without films.
- 4) Records produced by filming are impersonal, i.e. they treat all aspects of an operation with equal importance, unlike a human observation.
- 5) Films can study and time more than one operation simultaneously. This overcomes the difficulty of synchronising the studies of individual members of a team of operators.

---

\* The meaning to be given to each frame is affected by the limiting interval.



The advantages peculiar to Memo-Motion photography are due mainly to its economic superiority over normal cine-photography. At 16 frames per second one hundred feet of film will last just over four minutes, so that to film operations of longer duration than this requires two cameras, or stopping the operation while the camera is reloaded. Moreover, not only would the filming of a long job be very costly, but the analysis of several hundred feet of film, a very long and tedious process, would be prohibitive in time and money.

Thus a normal cine-camera is a very useful tool in limited circumstances, in industry where the majority of the work has cycles of less than four minutes. However, by supplementing normal cine equipment with Memo-Motion operating apparatus, a vast new field of study is opened at a relatively low extra cost.

The peculiar advantages of Memo-Motion Study may be listed as follows.-

- 1) It enables all the advantages of film study to be obtained at a fraction of the cost of normal filming. This statement must be qualified by stating that very short cycles may warrant the use of higher frame speeds than are obtainable with Memo-Motion equipment.
- 2) It permits cycles of longer duration than four minutes to be filmed continuously. One hundred feet of film will last 34 minutes at 2 frames per second, and this speed will supply all the relevant information required for the analysis of cycles exceeding one or two minutes.
- 3) It extends the use of the cine-camera into a field far exceeding its previous limited scope. Details of the field of application of Memo-Motion study have already been described in section 4 of this thesis.
- 4) It draws attention to major movements which do not follow Gilbreth principles. In a study of a continuous nature the projection of a Memo-Motion film at normal speeds will focus attention on bad movements, because they appear as rapid, jerky, motions on the screen, whereas they may pass unnoticed under visual observation of the actual operation.
- 5) It appears to be easier to install than either stopwatch time study or cine-photography, because of a more favourable attitude towards it from both management and men. This is a personal observation resulting from the experience of taking Memo-Motion equipment into industry for the experimental work described later in the thesis. Managements seemed to consider that the Memo-Motion camera is a more practical instrument than the normal cine-camera.

Employees definitely prefer to be photographed than timed with a watch, and in no case was there any difficulty with operators in the few Memo-Motion studies that have been performed.

- 6) It provides Work Study engineers with a more convenient means of convincing management that a certain operation or department is in need of improvement than is offered by the usual charts or diagrams.
- 7) Memo-Motion studies can be made on an operation or area without previously defining the particular aspect to be observed since the nature of the error involved is not always known. This is especially true in the case of area studies, where the causes of low productivity can vary tremendously.

This list of advantages would suggest that Memo-Motion could be applied universally, were it not for certain practical limitations of the system, deriving mainly from the difficulty of covering large areas with the camera, and the lack of detail that can be obtained on 16mm film.

The following list gives the disadvantages and limitations of Memo-Motion Study.-

- 1) It is not always possible to position the camera where it can cover the whole area to be studied. This is partly because the lenses obtainable for 16mm cameras have a long focal length in relation to the size of film, and hence a wide angle of view cannot be achieved.
- 2) When a fairly large area is being studied, even at half-second intervals, the film is too small to capture details of the hand movements of operators in the background. This means that if detailed studies are required of the movements made by individual operators in a large section, they must be studied separately or in small groups.
- 3) If the intervals between frames are too long, it is difficult to tell from the film what type of motion, if any, is occurring.
- 4) Utilisation Studies of machines or personnel, which use long regular intervals between frames, or random shots, can only show if a machine is running or not, and have no way of recording why a machine is not running. In some cases it may be possible to derive this information from the film, but generally it is not possible to distinguish between avoidable and unavoidable delay.



- 5) Memo-Motion films cannot be used for rating as well as analysis, and recording purposes, as Micro-Motion films sometimes are. This is not a major disadvantage, since rating is not usually required until well after the existing method has been studied and analysed, and a new method installed.

#### 5.2. General Conclusions Based upon the Results of Experimental Studies

The following conclusions have been drawn from the experimental work performed to gain information for this thesis.-

- 1) The use of a cine-camera and micromotion analysis equipment can be enormously increased by the addition to it of Memo-Motion operating apparatus.
- 2) Memo-Motion Study extends the technique of film analysis into industries which would not consider the application of Micro-Motion Study.
- 3) Memo-Motion Study can be used to replace Micro-Motion Study in many of the fields in which it is applied, notably in the study of repetition cycles exceeding one minute. In cycles of shorter duration than this the economic advantages of Memo-Motion are not sufficient to counteract the disadvantages of not having a normal record of the operation when projected at 16 frames per second.
- 4) Memo-Motion could be the means of introducing Work Study into industries, like the Aircraft Industry, whose problems do not lend themselves readily to solution by the existing techniques, and where apathy to Work Study exists.

#### 5.3. Recommendations for Future Work

Although this investigation into the application of Memo-Motion study has covered a wide field, it is obvious that there must remain other applications and techniques that it has not been possible to study fully.

This section has been written to suggest possible improvements, both to the apparatus and to the methods of using it, that may occur as a later development of Memo-Motion Study.

- 1) Experimental work into utilisation studies, using long intervals between frames, either of equal length or a pre-selected random length, has revealed the difficulty of visualising movement

from a single frame of film. This difficulty would be overcome by taking a very short run of film at every reading instead of a single shot. Three frames at half second intervals might reveal all the information required to indicate movements, so that what is required is a timing mechanism that will produce three impulses at given intervals instead of one. The timing mechanism constructed for this investigation could be modified to do this, in such a manner that by throwing a switch either one or three impulses could be obtained.

2) Randomised observations really require a better selection of random pulses than are obtainable from the timing mechanism described in Appendix 1 of this report. Obviously it is not practical to produce a pure random interval machine, but it would not be difficult to construct a device giving up to a hundred pre-selected random intervals between pulses before starting on the same cycle again. Such a piece of equipment would be a useful addition to Memo-Motion equipment.

3) A cine-camera is an expensive item, and it contains many features not necessary in a memo-motion camera. It would be possible to construct a camera solely for taking memo-motion pictures considerably cheaper than is possible for the complicated cine-camera. Such a camera would not be so versatile as a cine-camera with a memo-motion attachment, but would save a considerable amount of money, particularly as frame-by-frame projectors, with no shutter mechanism, are also very cheap.

4) It is possible that 9.5mm or Double 8mm film could be used for Memo-Motion studies, to further reduce the cost of filming, but it is felt that the amount of detail that could be obtained on the smaller film would not be sufficient for studying large areas, and the angle of view would be even smaller than that obtainable with 16mm film. Moreover special equipment would have to be made for the analysis of 9.5mm film, and this would counteract the reduction of cost available because of the cheaper film.

## 6. The Technique of making Memo-Motion Studies

A Memo-Motion Study requires.-

- 1) Preparation
- 2) Filming and Data Collection
- 3) Film analysis, and development of new method
- 4) Installation of new method.

The preparation function consists of deciding on the form of study and frame interval to be used, arranging the

location of the camera, discussing the study with shop personnel and supervision, and considering what supplementary information will have to be collected during the study.

The choice of frame interval will depend on the type of operation under study, and the degree of detailed information required on it. For example, if the operation consists of a single operator performing a light assembly with a cycle of about a minute, half second shots will be required, but if the machine utilisation of a machine shop is to be determined 1 frame per minute, using 2,000 frames or 50 feet of film in a week, will yield sufficient information.

A guide to the frame intervals to be used for individual studies may be obtained from Fig. 1, which shows the frame interval to be used on studies of operations of a given cycle or area for the type of information required. To use the diagram select the row opposite the work cycle or area size to be studied, move along to the colour representing the type of information required, which will be in the column giving the frame interval to be used.

The diagram should only be used as a guide, as each practical application requires individual consideration. An example of such consideration may be the desirability of adjusting the film speed so that a spool of film expires at a given time, say tea-break, so that a new spool can be loaded during a break in the operation.

To assist with the decision on the frame interval to be used for a given job it is as well to remember that 100 feet of film contains 4,000 frames, and will last one hour and eight minutes at one second intervals. It must also be pointed out that 4,000 frames take a long time to analyse, at least four hours on even the simplest job. Moreover there is a limit to the amount of analysis an observer can undertake without a break, due to the considerable eye strain resulting from the continual attention required, and the flicker of the projection lamp. For this reason it is recommended that the amount of film used for a given study is limited, if other considerations permit it, to one hundred feet.

In area studies the amount of film used can often be reduced by taking a short run of about half an hour at one second intervals, and filming the remainder at longer intervals. This will give information on the work of individual operators during the one-second study, and on man and machine utilisation, etc., for the rest of the study. If the work is of a repetitive nature it is quite sufficient to study a short period of it in detail, or if many operators are performing the same operation in an area study, it is permissible to study one or two of them in detail, and assume the others behave in a similar manner.

Having decided upon the frame interval to be used, the

actual process of filming is straightforward, and similar to both still and cine-photography. The modern film is both fast and tolerant, so that films can be taken in poor light, and accuracy of exposure is not critical. This is particularly true of films required only for analysis, where it is not necessary to produce technically perfect films. One study performed in very poor light in a steel mill was completely satisfactory, although the film was very badly underexposed, and could only be analysed by projecting it over a short distance onto a small screen.

It is essential to have a good range of lenses for the Memo-Motion camera, a one-inch and half-inch lens being a necessity. The lenses should have as wide an aperture as possible, and also be of the focussing type. Unfortunately it is not possible to obtain a half-inch lens with an aperture larger than f.2.8, although one-inch lenses go up to f.1.9. This may mean that in a very dark shop the wide angle half-inch lens cannot be used, although switching on normal shop lighting makes a surprising difference to the light content. In spite of the large apertures used, depth of focus is not a problem because of the very short focal-length of 16mm cameras.

The technique of film analysis is described fully in the sections of the thesis devoted to particular types of study, but it should be stated that the analysis forms the longest part of the actual study, and it is well worth the expenditure of money to make it quicker, easier, and more accurate. The first requirement is a good projector, preferably one that will project both continuously in both directions, and frame by frame. It should also be fitted with a frame counter. If the speed of projection can be altered so that Memo-Motion films can be projected very slowly it is a great advantage.

Many types of analysis, particularly of the machine utilisation type, require frames of a given nature to be counted. For example it may be required to find how much time a navy spends on Digging, Shoveling, Loading a Barrow, etc., and this would be done by counting the number of frames showing each type of operation. The counting process can be speeded up considerably if press button counters are used, either of a mechanical or electrical type. The mechanical counters are cheaper but slower to operate, and a bank of about ten counters, mounted together on a board, are recommended as part of the analysis equipment.

The problem of installing a new method derived from a Memo-Motion Study is no different to that used for the installation of any new method, and need not, therefore, be discussed here. It is interesting to note, however, that in the experience of one of the companies visited with the Memo-Motion equipment, installation took about 75 per cent of the total time of a study.

The techniques described in this section were developed

---

<sup>1</sup>. Lenses of 15mm focal length are now available with apertures of f/1.5



during the rather limited number of studies performed as part of this investigation, and so cannot be considered as final.

#### 7. The Use of Memo-Motion in Micro-Motion Studies

The practice of using a cine-camera to record operation sequences, with a view to analysing them in detail, is a well known and powerful tool in Motion Study. The construction of process or simo charts is made easier and more accurate, and any operation or portion of operation can be accurately timed by counting frames. Also rating may be performed during the filming or later at the analysis stage.

In spite of its many advantages the cine-film is not used universally in applying Motion Study, for an explanation of which Professor Barnes, of California University may be quoted.-

'.... With such a tool available (the cine-camera) it might be expected that its use would be universal. This, however, is not true, for a number of very good reasons.

First, micromotion study is not necessary in a large majority of the operations in a factory. One who understands the technique and the principles of motion study can, in most cases, visualise the operation completely and...determine methods that should be used. Motion study may be carried out in most cases without taking a motion picture and making the full analysis that micromotion study requires. Moreover, a micromotion study, although not prohibitive in cost, does require special motion-picture equipment, film, and considerable time for the analysis. Micromotion study for determining methods has a place in industry, although not so large a place as some maintain.

Micromotion should be treated as a tool.....something to be used when it is profitable to do so. .... In fact, a micromotion study is often the last resort, the procedure that is used when the application of the principles of motion economy to the job does not seem to produce the desired result. Sometimes in a complex operation it is difficult to get the motions of the two hands balanced without the aid of the simo chart, which is the graphic picture of the motions on paper.' \*

These objections do not apply to the use of Memo-Motion studies, where the cost of producing the information is reduced, because of the reduced cost of film and analysing, and greatly detailed information, for example finger movements, is not collected. Moreover the production of a Memo-Motion film is

---

\* Motion and Time Study, Ralph M. Barnes, M.E., Ph.D.  
Chapter 8, 'Micromotion Study'.

generally simpler than the production of a film for micromotion studies, since the apparatus for producing it is completely portable and does not rely on mains electricity supply, and longer exposures may be used so that lighting equipment is not required.

When the cine camera was first applied to Motion Study, by Gilbreth, the only standard camera available was the original hand-cranked one, so this was used, and later when clockwork motor or electric motor driven cameras became obtainable they were applied to micromotion study without considering if the 16 frame per second required for motion pictures was the best speed for analysing movements, in spite of the fact that one basic principle of work study is to challenge existing ideas. It must be admitted that there are advantages to using a film speed of 16 frames per second, one being that the operation appears normal when screened through a standard movie projector, so that the film can be used for operator training as well as micromotion study, and it must also be admitted that research workers have developed high-speed cameras for the study of very fast movements, but the development of slow speed cameras has been strangely neglected.

Thus from the above evidence it would appear that shots of wider spacing than 16 per second could be used for micromotion studies of jobs where intricate detail of small movements was not required, or where cycle times were of the order of a few minutes rather than seconds. In order to investigate this possibility tests were carried out, and it was found that the dividing line between micro and memo motion studies was not clearly defined, but there existed a range of jobs where the use of two or one frame per second filming yielded no less relevant information than 16 frames per second, at a fraction of the cost.

Hence a wide new field of motion study is thrown open, using a technique that could perhaps best be described as **MACROMOTION**, rather than either Micro or Memo Motion, using speeds of two or one frames per second.

In a work study department research into basic finger movements used in all assembly work, e.g. search, grasp, screw with fingers, and into optimum shape of bins or screwdriver handles etc., could be carried out in a laboratory using 16 frame per second or higher film speeds, leaving the actual operation studies in the shops to the faster and simpler macro-motion study. The camera evolved for the experimental work involved in preparing this thesis would be ideal for use in such a department, for it will produce either micro or memo motion films.

#### 7.1. Tests to Determine the Application of Memo-Motion Equipment to Micromotion Studies

It is obvious that for a system of recording industrial operations to be a success, no relevant movement should escape



the attention of the recording medium, in this case the camera. Having already shown that the short interval therbligs such as Search, Find, Select, etc., are of limited importance in practical applications, relevant therbligs may be defined as those which materially effect the progress of the work. i.e. Position, Assemble, Use, the function of collecting components or tools, and replacing tools. The Delay therbligs become of importance when the delay period is large, and will be included in a film taken at shorter intervals than the minimum relevant delay.

The fastest movement generally studied is that of moving the hand to collect or replace a component or tool, and hence tests were carried out to determine what movements could be caught by the Memo-motion camera.

The first of these tests utilised the Pinboard commonly in use as a demonstration piece to illustrate motion study. The operation was to fill the board with pins from a rack placed close in front of it, and the movements of the hands it involved represent the fastest likely to be encountered in practice. The operation was filmed at half second and one second intervals, the time for each cycle being 27 seconds, measured by counting film frames. Each hand handled 15 pegs, so that when filmed at half second intervals, when a total of 54 frames recorded the operation, three or four shots recorded the collection and positioning of each pin. The operation could be followed completely when filmed at half-second intervals, but not at one second, when pins appeared in the board with no apparent accompanying hand movement. The strips of film in figs. 2-3 illustrate this.

In this Pinboard test both the hand movements and grasping and locating of the pins were accomplished in a very short time, far shorter than would normally occur in practice, where the distance the hands have to travel is longer and components are not carefully arranged in the bins. Moreover practical assemblies take longer than placing a tapered pin in a countersunk hole.

Hence the second test was of a more practical nature - taking a nut and bolt from a bin on either side of the operator, screwing them together, and placing the assembly in a third bin in front of the operator. This cycle was filmed at half second and one second intervals, and it was found that the necessity to search for components in the bins prolonged the time the hand was at the bin long enough for it to be caught by the half second shots. Also the assembly period was fairly long, about three and a half seconds, and hence seven frames contained the assembly operation. The actual hand movements between the bins were caught by at least one frame in the half-second film, but sometimes missed completely in the one-second film. See Figs. 4 and 5.

In both the first and second tests the parts involved were very light, and the carrying distance short, resulting in fast hand movements. The third test was designed to lengthen these movements, and consisted in transporting plastic blocks from the sides to the centre of a bench, both hands working simultaneously. Two sequences were filmed, the distance of movement being longer in one than the other. In both cases the larger components slowed movement sufficiently to enable the half-second shots to record them adequately, as is shown in the film strips in Fig. 6.

As a final test on movement an experiment was designed to combine a slow, and fast, hand transportation. Heavy electric motor armatures were lifted from one side of the bench to a rack on the other. The movement carrying the armature was slow, followed by a swift return for another. The armature transportation was caught by three, and sometimes four, half-second shots, and the return empty by one. The whole operation was adequately recorded by the half-second film, (Fig. 7), and a further test on the same operation using one second intervals did record the movements, but with insufficient accuracy to be of any value.

These four tests were of an experimental nature, to ascertain if fast movements could be observed, and recorded, by using Memo-Motion equipment. In addition to these movement tests, an operation involving drilling 3/16in. thick light alloy plates on a bench drill, was filmed (Fig. 8). The plates were stacked on the bench and had to be lifted onto the table of the drill, about twelve inches above the bench. The plates were four inches wide, and hence the female operator had to stretch her hand to its maximum in order to pick them up. This particular operation had a cycle of eight seconds, and for motion study purposes was again adequately recorded by the Memo-Motion camera using frame intervals of half a second.

The result of these tests was to indicate that film speeds of two frames per second is adequate to study assembly work, providing the movements are not too swift or of such short duration that the analysis of finger movements becomes of importance. Obviously spaced shot photography could not be used for studies in the nature of coring tomatoes in a canning factory, referred to by Professor Mundel in his book 'Motion and Time Study', or very intricate assemblies like attaching the filaments of electric light bulbs to the electrodes, but there exist a wide variety of assembly jobs, having cycles of half a minute upwards, that would respond very satisfactorily to Memo-Motion study.

In order to distinguish between this type of study, virtually a logical extension of Micromotion study, and the more normal applications of Memo-Motion, the term used earlier, Macromotion, will be used hereafter to describe it.

## 7.2. A Macromotion Study of the Assembly of a Spray Gun

Following the success of the tests referred to in the previous section, the Memo-Motion equipment was used to study the assembly of a spray gun. The spray gun assembly had been laid out as carefully as possible, using the established principles of motion economy, and this procedure was filmed at two frames per second to see if it could be improved.

Bearing in mind that the operation had already been investigated, and an efficient procedure determined, the results of the film analysis were most gratifying, and effected a saving of time by eliminating time-consuming delays, and altering the assembly procedure to improve lengthy sequences, as well as correcting several bad body movements which were clear in the film but passed unnoticed during the visual observation of the operation.

The actual time saved on the assembly was 22 per cent, the cycle time being reduced from 5 minutes  $1\frac{1}{2}$  seconds to 3 minutes 53 seconds.

Had this operation been filmed at 16 frames per second it is unlikely that any further relevant information would have been obtained, and, moreover, the original cycle could not have been filmed continuously at normal speeds because the 100 feet film spool commonly in use only last 4 minutes and 10 seconds. Thus to perform a micromotion study, the operator would have to stop at the end of four minutes and wait for the camera to be reloaded, or else the final part of the operation would have to be filmed on another cycle.

As the spray gun assembly was the first practical application of a Macromotion study, no film analysis procedure had been developed, so the spray gun film was used as a basis for the evolution of a formal system of analysis, on the lines of that already in use for Micromotion films.

The analysis of the spray gun film is, therefore, described in the section 'Analysis of Macromotion Films', as an example illustrating the method evolved.

## 7.3. Analysis of Macromotion Films

The system developed for analysing Macromotion films is similar in principle to that already in use for Micromotion films, and involves the use of a modified set of therbligs and the construction of simo charts. The simo chart summarises the information contained in the film in a convenient form for further study and development into a new method. It emphasises lengthy operations and delays, and out of balance movements.

A modified list of therbligs has been devised, consisting of only nine elements instead of the original sixteen used by Gilbreth. The new therbligs combine several of the original ones into a larger element capable of study by half second shots. In all cases only those movements which would be difficult to shorten by motion study principles have been grouped together, for example, the act of bringing in a new component or tool to the work area has been reduced from.- Transport Empty - Search - Find - Select - Grasp - Transport Loaded, to simply 'Collect', which covers all these elements.

As far as was possible the new therbligs were made to conform in symbol, colour code, and description, with the originals, and a full list of them is shown below.-

### 7.3.1. Macromotion Therbligs

#### → 1. Collect (Green)

'Collect' refers to the act of bringing to the work place a component or tool. It begins at the time the hand leaves for the component, and ends when the hand has reached the work area. It is usually followed by 'Position', 'Use', or 'Assemble'.

#### 9 2. Position (Blue)

A movement preparing a jig, component, or tool, for further action. For example position a component in a jig prior to working on it.

#### # 3. Assemble (Violet)

'Assemble' is the movement putting components together, for example screwing a nut on a bolt, or a bolt into a main component.

#### U 4. Use (Purple)

'Use' refers to the function of applying a tool or device to its designed function, for example tightening a nut with a spanner. 'Use' and 'Assemble' are the movements which materially affect the state of a component by doing work on it.

#### ∩ 5. Hold (Red)

Hold describes the use of the hand to store a component or tool, or to grip a component while the other hand performs work on it, for example holding a bolt while a nut is screwed on it. It is appreciated that this latter function does not really come



5. Contd.

within the scope of holding, and does in fact assist in the assembly, but as one of the objects of motion study is to avoid using one hand as a vice, it is felt that calling such a movement 'Hold' and colouring it red will bring more attention to it than if it were referred to as 'Assemble'.

← 6. Replace (Olive Green)

This function refers to the replacement of a tool or component after use. The movement is distinguished from 'Collect' because it will usually be used immediately preceding it, for example in the spray gun analysis, Replace Box Spanner is followed by Collect Guide Cage. Thus if they were covered by the same therblig it would not be possible to distinguish between these movements on the simo chart.

-0 7. Unavoidable Delay (Yellow Ochre)

This covers a pause forming part of the cycle of operations, and outside the control of the operator, as when one hand has to wait for the other to complete an operation before it can resume work.

Q 8. Avoidable Delay (Lemon Yellow)

This covers stoppages due to a fault in the operator, either fumbling with one hand causing it to fall behind the other, or as the result of incomplete learning if one hand has a delicate operation to perform.

p 9. Rest (Orange)

The function of pausing to overcome fatigue, only considered as 'Rest' if the pause forms an approved part of the cycle, otherwise 'Avoidable Delay'.

7.3.2. Preliminary Analysis

The analysis is commenced by running the film through a number of times on a normal 16 frame per second projector, which obviously presents a speeded up version of the operation. These 'fast motion' films are readily followed if the frame intervals are a half or one second, but if the intervals exceed this, the projected film is too fast to follow logically.

From the cine projection will come a familiarisation with the operation, and also the germ of a means of improving it, for the effect of seeing the operation quickly is to magnify

and make noticeable, faults that would pass unnoticed if seen at normal speeds. Excessive hand or body movement is an example of this, as they are seen as rapid, jerky, motions.

### 7.3.3. Construction of the Simo (Simultaneous Motion) Chart

Having studied the film in the manner described in the preceding page, a frame-by-frame projector, fitted with a frame counter, is used to make the detailed analysis of individual shots. A simo chart of left and right hand operations is used.

The work of making out a simo chart is greatly simplified if a Process Chart of the operation is available, or at least an assembly sequence, and it may be worth producing such a chart prior to starting on the simo chart. One sheet of the simo charts of the Spray Gun Assembly, original method, is shown as Fig. 9. The whole chart covered eight sheets, which may seem large, but it should be noted that had 16 frame per second film been used, it would have occupied 64 sheets.

The time taken to produce this chart, from the film, was two hours for two operators, working directly on the typewriter.

### 7.3.4. Analysis of the Simo Chart

The process of filming, and using the film to produce a simo chart, completed the function of recording the facts of an existing procedure. The next step is to examine the facts critically with a view to developing a new method.

The procedure of analysing a simo chart produced from a macromotion film is basically similar to that already in use for those produced from micromotion films, and need not be discussed in full here. It consists mainly of trying to eliminate delays, cut down operations, balance movements between the hands, cut down the number of 'Collects' by picking up more than one component at a time, and eliminating 'Holds' with one hand while the other works.

It should be noted that it is not necessary to use both the symbol and colour codes for therbligs. The colour code is most distinguishable, but takes longer to use, and in many cases the symbol code only would be sufficient. In the same way it is not essential to use special printed sheets for simo charts, ordinary inch and tenths graph paper is sufficient, and would be more economical in use.

Reference to the simo charts of the original method of assembling the spray gun will give examples of time-wasting elements.



- 1) On page 1 the right hand has two small delays and two holds.
- 2) On page 3 there are two lengthy operations, winding packing round needle, and screwing in gland nut, as well as two small right hand delays.
- 3) A very lengthy operation is seen on page 4, which is simply putting in one screw, the time involved being due to a faulty end on the thread. There is also a right hand hold on this page.
- 4) On page 5 is another long operation with the left hand, and hold with the right hand.
- 5) Page 6 reveals almost continuous delay or hold with the left hand, and a delay with the right hand due to fumbling and dropping a screw.

These are typical examples where there is room for improvement, sufficient to show the capabilities of this type of study. The simo chart will also yield such information as total 'Hold' time, 54 seconds in the case of the spray gun, with 34 seconds of delays. It may be necessary to refer to the film again when seeking for a means of solving the faults in an existing method, for example the fumbling on page 6 was prevented by turning the jig round before endeavouring to insert the screw. On the other hand the solution may come by the alteration, or incorporation, of a jig, the method used to reduce the two long operations on page 3, where the use of a jig to compress the packing round the needle reduced both the time to insert the packing and the time to screw in the gland nut. Another means of improving an operation may involve slight modification to the design of components, an example of this occurring in the spray gun analysis, where the use of a new make of screw with a slight lead on the thread greatly reduced the very long operation on page 4 of the simo chart.

Thus it will be seen that there can be no rigid procedure for analysing a simo chart. The chart simply draws attention to possible errors, finding the solution to these errors relies on the ingenuity and experience of the individual performing the analysis.

One sheet of the simo charts of the improved method of assembling the spray gun is shown in Fig. 10. Study of it will show a reduction in the number of delays, better balance between the hands, less very long operations, and fewer cases of one hand holding a component while the other works on it.

### 7.3.5. Analysis of the Film for Bad Movements

Movements which are unnatural, or involve considerable stretching or twisting, or lack of symmetry, have a bad effect on time for operations, and cause more fatigue than smooth and easy actions. The film scores heavily on recording such bad movements, and the spaced shot film is no less efficient in this respect than the continuous film.

Bad movements can be eliminated by altering the bench layout, or the position of the operator, or, if necessary, by the redesign of jigs. It is not difficult to decide which of these courses is the best, because it is usually obvious from the Memo-Motion film.

The spray gun assembly film was analysed for bad movements, and found to contain many examples which could be eliminated by a simple re-arrangement of the work bench. Some examples of bad movements found in this film are shown in Figs. 11-13 and illustrate the ability of the Memo-Motion camera to record these errors of movement.

## 8. Application of Memo-Motion to Area Studies

Many types of industrial operation involve more than one man working together, on the same job or in the same area, but not as a team. Area studies vary from the study of one person at a single bench to a whole factory floor, involving perhaps hundreds of men. It is obvious that the information obtainable from a film of two such extremes will differ widely, for in the case of the single operator details of the actual process will be recorded, but in a study of a large factory floor the details of individual processes will be obscured, and only information relevant to the working of the whole area, for example man and machine utilisation and shop layout, will be recorded by the camera.

This point is illustrated in the film of the Aileron Assembly Department in an aircraft factory (see Fig. 14). It can be seen that the process may be studied in the case of the two operators in the foreground, but details of work in the jigs in the background cannot be observed.

Hence it will be seen that the approach to the study of an area will depend on the size of the area in question, and the information required from the film. Generally speaking if information of the actual process followed by operators, the camera will have to be set to cover a small area using short frame intervals, while if floor layout is to be considered the area covered should be as wide as possible and frame intervals of up to a minute used. (See Fig. 1).

### 8.1. The Information Obtainable from Area Studies

As has been stated earlier, the information in films of area studies will depend on the size of area, type of operation, and film speed used, but the following list typical information obtained in practice.

- 1) Details of the process followed by individual operators. This information will be slight if the area is large, or if the frame intervals used are long in relation to the movements involved in the job.
- 2) Operator Movement, i.e. the movement necessitated by the job in the particular section of the area.
- 3) General Operating Movement, the movement over the area of operators collecting stores, moving components, sweeping the floor, etc.
- 4) Material Flow through the department.
- 5) Workplace layout, the layout of individual jigs or benches.
- 6) Shop Layout, the overall layout of jigs or machines in relation to each other, and the shop in general.
- 7) Man or machine Utilisation.
- 8) The effect and efficiency of Supervision, or Roving Inspection.

In the above list only information liable to effect production has been mentioned, There are other less important, but interesting, facts which may be recorded, for instance it was noted in one film taken in an Aircraft Assembly shop that many of the operators spent an appreciable amount of their time scratching their heads, one actually doing it 40 times during an afternoon. It does serve to indicate the very fine detail of information that Memo-Motion can yield compared with that obtainable by other methods.

As area studies are very applicable to many branches of industry, and Memo-Motion equipment is likely to yield very good results in them, a considerable amount of experimental work has been performed in this field. The results of these experimental studies have been used to develop a procedure for analysing area study films, and have also illustrated most convincingly the amazing amount of movement that occurs in all types of floor work.

Micromotion and Macromotion films of single operators will not only reveal errors in an operation, but will also

suggest a means of improvement. For example, a film may show a bad movement due to a badly located jig or bin of components, and this will suggest a re-layout of the workbench. Some area study Memo-Motion films will also suggest means of improvement as well as pointing out errors, but as the time interval between frames becomes larger this factor will diminish, until with very long intervals no indication of possible improvements will come from the film. Thus in studies of Machine Utilisation, using about 200 frames per day, the actual percentage of down time to total time will be recorded by the film, but it will not reveal what caused the figure to be either high or low.

The analysis of Area Study film is discussed in Section 8.2, giving examples of actual studies performed. In addition to these full studies, various short tests on areas were performed at differing frame speeds in order to ascertain what information could be obtained. These results have been used to construct the film speed chart (Fig. 1) and to draw general conclusions on Area Studies, but they are not important enough to warrant description here, although a few strips of film have been included in Figs. 18, 19 and 20.

#### 8.2. The Analysis of Area Study Films

It is obvious that with so wide a variety of jobs covered under the general heading of Area Studies, the procedure for analysing the film will depend on the particular type of operation studied.

The procedure followed for analysing a film of a few operators, taken at short intervals up to 1 second, would be similar to that described in Section 7 for macromotion films, i.e. Simo Charts or Operation Charts would be prepared for each operator, and each considered separately. The film would then be further studied for factors liable to affect the production of the group as a whole, for example the area layout may be capable of improvement, particularly in respect of collection and handling new parts from stores.

All films, with the exception of those taken at more than three second intervals, should be projected at 16 frames per second a number of times, to familiarise the analyst with the general working of the area, and to give a lead on the best system of analysis, and the main points to be studied.

For subsequent detail analysis it is best to illustrate typical procedure by referring to particular examples, for each individual analysis will depend to a great extent on the particular situation under study, and the information required from the film.



### 8.2.1. Analysis of Film on Aircraft Aileron Assembly

Two points must be made clear before describing the analysis of the film, and they are.-

- 1) This film was taken to see what information Memo-Motion studies would reveal, rather than to solve a specific problem regarding the manufacture of this particular aileron. Thus the film was, to some extent, a shot in the dark, and the frame intervals chosen are not necessarily recommended for studies of a similar nature. Fig. 1 will give information regarding the correct intervals for a given study.
- 2) Aircraft manufacture is a specialised branch of engineering, and has problems peculiar to itself, due mainly to low manufacturing quantities and the necessity to obtain a high degree of accuracy on assembled sheet metal parts. The existence of A.I.D. specifications for nuts and bolts and rivets complicate the handling of these parts, since the stores system has to be more rigid than is common in other industries. Hence when analysing the film it is impractical to suggest that expensive re-design should take place on jigs and fixtures, or that larger supplies of rivets and consumable details be kept at the work bench.

The area under study was responsible for the manufacture of the control surfaces of a light aircraft and the jigs in the foreground of the filmstrip (Fig. 14) were first stage assembly fixtures, where the leading edge structure was built up.

The construction of the leading edge is typical of that used in control surfaces, a front spar carrying leading edge ribs and the operating levers, covered by a light skin. The first assembly stage consists of building up the ribs on the spar, trimming the skin to profile plates on the jig, drilling through the skin and ribs (guided by drill bushes in a swinging drill plate on the jigs) and finally blind riveting the skin to the ribs and spar. The work was very light, and the only power tools required were pneumatic drills. The operations are typical of those found in light aircraft fitting.

The camera was focussed on a row of four assembly jigs, involving five operators, three men and two girls. As can be seen in the film strip, floor space was at a premium in the factory, and to the right and left of the area under study can be seen jigs for the final assembly of control surfaces and the cockpit canopies.

One hundred feet of film was expended during the study, which began at 1.20a.m. and continued until 4.00a.m. The first

25 minutes were filmed at 1 second intervals, and for the remaining time an interval of 3 seconds was used. Varying the interval between frames during the study allowed the actual movements of operators to be studied over a short period and these were considered to be typical for the whole period. This practice has since proved to be very sound, particularly with repetition work.

Reference to the film strip will show that the two operators in the foreground, one man and one girl, can be studied carefully, but that those working at the jigs behind them are too far away, and partly obscured by jigs, to be studied in detail. It is possible, however, to see if they are working at the jig or not, and hence an overall utilisation factor could be obtained.

The function of the girl in the foreground is to perform the easier parts of the assembly, leaving the difficult parts to the man. It was felt by the supervision that it would be cheaper to employ one man and a girl in this manner than to use two men, but in the 16 frame per second run through of the film it appeared that the man was having to spend a good deal of his time helping the girl, who would continually call him over for assistance. In the detailed analysis it was decided to check this factor, the man's time being divided into three categories, (1) working at his own jig, (2) helping the girl, and (3) non productive time, i.e. time spent away from the work area, or not working within it. The figures obtained from the analysis confirmed the impression gained during the preliminary run through of the film, and they are as follows.-

Time working on own job	... 34 per cent
Time helping girl	... 40 per cent
Non productive time	... 26 per cent

These figures show that it would probably be cheaper to hire another male operator instead of the girl.

The film also shows that 45 per cent of the working time on the aileron is out-of-jig work, trimming the skin to lines scribed on it in the jig, deburring holes, filing a cut out at the operating lever end, etc.

The percentages were obtained from the film by using button operated counters to record when a certain category of work occurred. Two of these counters were available for the analysis, but they were not enough. For the three categories mentioned above, i.e., time on own job, time helping girl, and non productive time, the two counters were sufficient, and the non productive time was obtained by subtracting the sum of the first two from the reading on the frame counter fitted to the



projector. However the film had to be run through again in order to sub-divide the time the man was engaged at his own job into in-jig and out-of-jig time. It is obviously worth the expenditure of a few extra pounds on the cost of filming apparatus to provide a number of counters to add the number of frames showing given information. It would be possible to make out a chart, similar to a simo chart, using a different colour to represent various functions, colouring a division for each frame, but as the divisions have to be at least one tenth of an inch long, a total of 400 inches of chart would be required for a 100 feet film. It is considered that such a method of analysis would be uneconomic and a counter system is preferred.

Other information obtained from the film of Aileron Assembly is as follows.-

1) The bench in front of the jig used by the male operator in the foreground was badly laid out for the out-of-jig work. The operator's tool box can be seen at the left hand side of the bench, and there is a drawer for his large tools at the right hand end. Most of the work done on the bench is at the Root End of the Aileron, which the operator places at the right hand end of the bench, and hence he has to continually walk the length of the bench to get his tools from the box. It is interesting to note that the operator did this seven times during one five minute period, and then realised that the camera was on him, so he turned the Aileron round on the bench, only to find that he then had to walk along the bench to get the tools from the drawer. Simply by repositioning the toolbox at the other end of the bench this walking could have been eliminated. There was a box of rivets under the bench, but they were not used at any time during the study by the operators in this section. They were, however, used by a girl who came from some other jig outside the area, who collected some periodically, disturbing both the operators in the section as well as wasting her own time.

2) The Inspectors, two of whom toured the jigs periodically, held up the operator for a considerable time. Inspection staff cannot be eliminated, but these two caused hold ups by spending a considerable time talking, etc.

3) The detail parts for the ailerons were stored under the bench, so that the operator had to bend down and pick them up at the beginning of each aileron. This took considerable time because the parts were not stacked neatly, or the ribs placed in order, so that the operator had to sort the correct ones out of a large pile. On one occasion the operator could be seen to spend some time searching for a particular rib, and being unsuccessful, he went off to the stores, returning in three minutes with the required part. This indicates that a more efficient system of handling the components is desirable, one possibility being that the stores sort detail parts into

aircraft sets rather than batches of similar parts. These sets of parts could then be issued to the works and the time of skilled men on sorting components would be eliminated. In the majority of finished part stores the storemen have ample time to do this sorting in the periods in which they are not serving.

4) On completing an elevator the operator took it off to a buffer store before the next assembly stage. He spent a few minutes looking for the Job Card which had to accompany it, and also a label which he stuck to the skin. He took three minutes to carry the aileron to its destination, making a total of  $6\frac{1}{2}$  minutes spent disposing of the completed component. The girl could very well have performed this function, or the man could have put the aileron in a rack for collection by a labourer.

5) The lack of floor space in the factory made it necessary for men working on the canopy section, to the left of the area studied, to store one of their canopy frames, a bulky magnesium casting, in the gangway between two of the aileron jigs. This canopy, which can be clearly seen in the film strip, caused congestion in the aileron section, and should not have been stored there.

6) The two operators working on the jigs in the foreground had only one pneumatic drill and blind rivet tool between them. This caused delay in the relatively short period that was filmed, and over a longer period must certainly have resulted in considerable waiting on the part of one of the operators, as a very large part of the operation consisted of drilling or riveting.

These examples of faults found in a short study of the area, coupled with the figures of total labour utilisation that more detailed analysis would have yielded, illustrate the thorough investigation possible with the camera. The time taken to produce this analysis, working as a single observer and developing a procedure as the analysis progressed, was three hours. This was not as long as the period covered, and is a reasonable time as a standard for analysing 100 feet of film, provided there are counters available.

#### 8.2.2. Analysis of Film on Aircraft Tailplane Assembly

The comments regarding certain production limitations peculiar to the aircraft industry made at the beginning of the last section refer also to this study, which is of the final assembly tailplane shop of a factory producing a high speed super-priority fighter. The construction is considerably heavier than that of the control surfaces of the light aircraft, and dimensional tolerances much closer, hence the assembly jigs are far more complicated and expensive, costing in the order of £1,000 each. At the time of the study eight jigs were in use,

and because they could not meet the production requirements, a further row of jigs were under construction.

The high cost of the Assembly Jigs makes tooling costs a high proportion of the total assembly cost of the tailplane, and hence an obvious criterion of production efficiency of the area under study was the Jig Utilisation Factor.

Fifty feet of film were used over a period of four and a half hours, a frame interval of eight seconds. This gave 2,000 snap readings of the activity in the area, an amply large sample for statistical purposes. Four jigs were covered, as well as the out-of-jig work on the tailplane. The jigs were classified as productive or non-productive, depending on whether any operators were working on them, and not as to whether there was a tailplane in the jigs.

The number of frames in which each jig was idle was recorded on the counters referred to previously, the productive time being obtained by subtracting the counter figure from the total number of frames analysed.

From the study a Jig Utilisation Factor of 43 per cent was obtained which means that if this was the average over a long period the extra production required from the section could have been achieved by raising the utilisation of the existing jigs rather than building expensive new ones.

In order to obtain a reliable figure of utilisation the study would have to be over a period of about a week, since the particular afternoon studied may have been a bad one due to some external factor, for example a shortage of parts. One hundred feet of film would be sufficient for such a study, since it has 4,000 observations. The frame interval used would be 40 seconds.

Although Jig Utilisation was the most important factor in this study, and was in itself capable of saving the company several thousands of pounds had they only known it, other interesting facts did emerge during the study. They are:-

- 1) The operator in the foreground spent 3.1/4 hours screwing a cover plate over the root fittings. This plate was a 10 S.W.G. sheet 14 inches by 10 inches, held down by about 20 countersunk screws into anchor nuts. The cut-out in the skin was marked in a previous jig, and filed to this mark by hand, the clearance between the skin and cover plate being not more than 0.015 inches. The cover plate was blanked to profile, and completely drilled and countersunk, and hence there was no reason why it should have taken more than ten minutes to attach it to the tailplane. The film could not show why this time was taken, except that on one occasion the operator was seen to be

searching in the box containing the screws for three consecutive frames, a time of at least 16 seconds, subsequent examination showing that the box contained not only the screws, but also a complete assortment of odd nuts, screws, washers, rivets, etc. An investigation into the earlier operations on the skins revealed that operators were leaving a few thousandths of an inch of metal around the cover plate, for fear of scrapping a whole skin if they took off too much. This meant that skin had to be trimmed at the final stage when it was impossible to get a file on the edge, and the only way of removing the offending metal was by means of a rotary file in a pneumatic drill.

It would not be easy to measure utilisation without a Memo-Motion camera, since the men obviously take care to be working at the jigs when the supervisors are in the area, this fact being verifiable from the film.

A strip of the film is shown in Fig. 15. It indicates the degree of detail recorded in an area film, but that the sequence of any series of movement cannot be determined by eight second interval films.

### 8.2.3. The Analysis of Film on Aircraft Wing Assembly

The two previous area studies were primarily concerned with the operations of a particular employee, and jig utilisation. This study was intended to cover actions of four men working together on a pair of assembly jigs, with a view to improving the area layout rather than to consider the cycle of operations of the job.

Aircraft assembly is highly complicated, and the total cycle time of a wing in the jigs studied was in the order of three days. The wings were built in pairs, one port and one starboard, in the jig, and the four men were split into two pairs, the first pair being erectors, who build up the internal structure, and the second pair skimmers, who skin the wing after the erectors have completed their work on it. The cycle times for these two portions of the assembly were approximately equal, so one pair worked on one wing while the other pair perform their part of the assembly on the opposite hand wing.

It was felt that the best way to study the operation was to film a short period of it at one second intervals, so that detailed information of the manner of working could be obtained. One hundred feet of film were used, covering a period of one hour eight minutes.

The film was analysed by first running it through at normal projection speeds and then making a detailed frame-by-frame analysis.



The first fact which became immediately apparent from the cine-projection of the film was the chaotic manner in which people from other parts of the factory came to the area under study to borrow tools, try components on the wings, or merely to talk. There were supposed to be four operators in the area, with an occasional labourer to sweep up, but there were seldom less than six people, and the disturbing effect of this intrusion was very obvious from the film. Hence a fair saving of everyone's time could be effected by a more efficient planning of tool distribution.

Another fact which emerged from the cine-projection was that the men spent too much time walking from one side of the jig to the other. This was particularly noticeable in the case of the erectors, because one of the pair was engaged in filing a root fitting in a portable vice, leaving the other man to carry on with the erection, which necessitated him walking round the jig to do work which would normally be done by his partner. The skimmers also spent a lot of time going from one side of the jig to the other, mainly to pick up tools or rivets from trays which were placed round the jig with very little thought as to their best position.

The skimmers, whose main function was riveting, also climbed up and down the trestles they used when working on the higher parts of the wing on far too many occasions, again to pick up tools or rivets.

The cine-projection of the film yielded yet more information on bad workplace planning, for on three occasions men were seen searching for something, either in a box which contained numerous assorted components, or under racks or duckboards, and there was no provision for stacking or storing new components, an example being a bundle of stringers propped up against the side of the jig, which was knocked down by an operator once during the hour the area was studied.

This information obtained from a normal projection of the film, condensing an hour's work into four minutes, shows the value of the preliminary projections. The film was projected a total of five times in this manner, running it back to study some sections until a clear picture was formed of possible ways of improving the area.

It may be that enough information would be gained in this manner without going to the expense of a detailed analysis, which would, to a large extent, only add positive figures to the general impressions gained from the cine-projection. Also it should be noted that the area under study had never been methodically studied to the slightest extent before the film was taken, so that it would be best to get the area running efficiently by acting upon the information obtained from a preliminary study

before making a detailed study of a set of circumstances which are known to be bad.

However, as an illustration of how a film would be analysed in detail to improve workplace layout, an Operator Movement Diagram, which is virtually a string diagram drawn on paper, was produced and used to suggest an improved layout. A strip of film is shown in Fig. 16.

One fact that emerges immediately from a study of the movement diagram is that none of the four operators working on the jig use tools or components from the rack in the centre of the jig. The film showed that other operators from outside the area often came in and took articles from this rack, and subsequent investigation, if it were possible, would almost certainly reveal that the tool boxes on this rack belonged to some operators in another adjacent area, rather than to those actually working on the jig. The reason why boxes of tools may find themselves separated from their owner in an aircraft factory of this sort is that the manpower is kept flexible and not necessarily on the same jig all the time. The area under study covered one of a line of jigs, and it is very likely that the operators fluctuate between the jigs, leaving their heavy tool boxes in one of them.

The majority of movement made by the erectors was in collecting tools, and the riveters in collecting rivets. Having produced the movement diagram, evolving a better layout is a matter of personal decision, based on company policy in the particular factory.

As a suggestion towards the solution of the rather complex problem of positioning the toolboxes of the various operators, it is felt that each operator should be provided with a small case in which to carry the tools most likely to be used on a given job. Most fitters collect a large quantity of tools, some of them heavy and cumbersome, that are very seldom used when working on a repetition job. These could be left in the box, and only the regularly used ones carried about to various jigs. If the cases were provided with hooks that would clip them to the channel members of the jigs at a convenient height even more time and energy could be saved.

The obvious solution to the problem of rivet collection is to provide trays for them in the place they are used, in the particular case under study this would be along the top channel member of the jig. This would save the men continually climbing down from the trestles in order to pick up handfuls of rivets.

Finally, the problem of positioning the components required in the assembly could be solved very neatly in the manner described in Section 6.2.1, by having them made up into aircraft sets in the stores and issued to the shops as a complete

kit, preferably in some form of container. Consolidated Vultee Aircraft Corporation, of California, have applied this system, and send out sets of parts for assemblies on wheeled racks. They claim a considerable increase in production due to the installation of the method.<sup>x</sup>

The manufacture of special cases for tools and racks for components may be thought to be too expensive, although they would be standard items with a long life, and could be used on other jobs. In this case a simpler method would have to be devised, but this study has shown that Memo-Motion can produce the facts, analysing the facts being a routine application of Work Study principles.

The study may be criticised in regard to the length of frame intervals chosen. In a study of as large an area as this, it is impossible to determine individual movements of an operator because the detail is so small, and there is little to be gained by filming at one frame per second. Two second intervals between the frames would have produced all the relevant information contained in the one-second film, this fact was verified by checking the analysis at every other frame, and only used half the film or better still, covered twice as long a period.

#### 8.2.4. Analysis of Film on Roller Bearing Wrapping

This particular area study was a study with a purpose, to solve a problem rather than an experiment to see if Memo-Motion was applicable to the particular operation under study.

It concerns a department responsible for wrapping roller bearings. The company wished to improve the productivity in the department, and were willing to make considerable changes to achieve it. At the time of the study the Efficiency Department were experimenting with a system of packing the bearings in cartons of six instead of wrapping them individually in paper.

The bearings come into the department from the assembly shop, which it adjoins. They were transported in wire mesh trays, sixteen inches square and eight inches deep. They were greased in these trays by dipping them into a bath, so the trays and bearings were very oily during their passage through the wrapping section.

---

<sup>x</sup> Photographs and a description of the system employed by Consolidated Vultee are included in an article by the Manager, Mr. B.F. Coggan, in Modern Materials Handling, December, 1953.

Bearings ranging in size from  $1\frac{1}{2}$  inches outside diameter to 9 inches outside diameter were catered for, and some customers asked for special types of wrapping, or different numbers of bearings in the same package. A further complication arose from the special wrapping of bearings for export. These bearings go through the wrapping department but were not wrapped there, being sent to another shop for special packing.

After wrapping, the bearings were taken on small trolleys to the Packaging department, where they were put into boxes for transport. The Wrapping and Packaging departments were separated by a store, so that the bearings had to be moved some considerable distance down a corridor between wrapping and packaging. One of the improvements envisaged by the company was to re-arrange the factory layout so that these two shops adjoined each other.

The Wrapping department was manned by 15 girls and 7 labourers, the girls working mainly in pairs with one girl wrapping and the other feeding her with bearings out of a tray. The function of the labourers was to transport bearings around the department, and into the Packaging department, and also to collect empty trays for degreasing.

The department acted as a store between assembly and dispatch, there being a large bench area, with roller conveyers, on which the trays of bearings awaited wrapping instructions from the Sales department. There was often some considerable delay in the receipt of these instructions, so bearings and labour were kept waiting.

The wrappers received instructions from the foreman as to which bearings to wrap and carried the wrapping materials to the bearings, so there was no set workplace for the individual girls.

The company were interested in speeding up the wrapping time, so that the interval between completing the bearings and delivering them could be reduced, and also in saving labour cost and floor space in the department. Before starting on the actual re-organisation of the department, the Efficiency Engineers required the following information.-

- 1) The exact nature of the wrapping operation, the amount of work done by each girl, and the proportion of time spent on (a) wrapping, (b), stacking bearings on the bench or on trolleys after wrapping, (c) collecting new trays of bearings, (d) preparing for a new job, and (d) non-productive.
- 2) The amount of general movement in the shop caused by the girls being mobile and the bearings stationary. This information was required because one of the



possible improvements would be to make the bearings come to the girls at fixed work places, where the wrapping materials could be more efficiently placed.

- 3) Arising out of (2), information was required on the number of trays of bearings on the benches in the area. This was to give an indication of the number of trolleys that would be required to form a mobile store for the bearings if the benches were removed.
- 4) The function of the seven labourers in the section. No fixed definition of their work was available, and it was thought that their number could be reduced.

To have produced this information by normal visual observation would have been lengthy and not very accurate, since the department would not have worked in its usual manner if a team of observers had followed each operator and labourer to record their actions.

The area was studied for a full day, using three hundred feet of film. One second intervals were used for the first hour, and the remainder of the day filmed at three or four second intervals. The one-second film was used to study in detail the movements of one pair of girls on the wrapping, and the longer interval films gave the information on general movement and tray requirements. The amount of work involved in analysing the three hundred feet of film was considerable, and six-second intervals could have been used to cover the main period of the day, retaining the one hour of one-second filming. This would have reduced the amount of analysing by one third without seriously effecting the amount of information produced.

All the information required by the company was recorded in the film, and the analysis was performed by the method already described in the previous sections on Area Studies, that is by making a preliminary analysis during projection at 16 frames per second followed by detailed frame-by-frame analysis.

The four different types of information which were required were studied separately, rather than attempting to record all the details at one analysis. The wrapping operation was analysed by selecting one pair of girls who could easily be seen on the film, and preparing a simo chart of their actions. From this chart the percentage of time spent on each of required headings was obtained, and the relationship between the work of the two girls. The accuracy that was demanded on the detail of the operation necessitated the use of a one-second time base for the chart, which in turn meant that the whole chart occupied 50 pages.

The figures obtained for the proportion of time spent on each of the five categories of activity are shown below.-

	OPERATOR A	OPERATOR B
	%	%
Wrapping	46	54
Stacking	16.6	4.4
Collecting New Trays	2.4	2.5
Preparation	2.5	1.5
Non Productive	32.8	37.7

The study also showed that the pace during the wrapping operation was set by the girl actually wrapping, the girl lifting the bearings out of the trays working quite slowly. Employing two girls as a team on the wrapping undoubtedly increased production, but not productivity, as one girl could have done more than half the work of two.

The amount of movement caused by the girls having to go to the work was very noticeable when the films were projected at normal speeds, and it was not necessary for string diagrams to be constructed to show this since the people who had to make the decision to alter the layout were convinced by seeing the film that it would save time to do so. This will often be the case when applying Memo-Motion, since diagrams are often constructed simply to convince management that a change would be advantageous, and a Memo-film is a much more effective way of doing this.

The number of trays in use in the department was ascertained by counting all those which could be seen at selected intervals. One hundred readings were taken, spread out over the day, the trays being divided into two categories, those containing bearings to be wrapped in the department, and those containing bearings for export. These latter trays were kept on a bench separate from the others. The figures obtained in this manner are quoted below.

	Bearings to be wrapped in the department	Bearings to be wrapped out of the department
	No. of Trays	No. of Trays
Maximum	62	52
Minimum	25	14
Average	36	42

These figures will enable the number of trolleys required to handle the production of bearings to be ascertained. It is

interesting to note that the number of trays containing bearings to be wrapped in the department fell gradually during the day, but those containing the bearings for export remained roughly constant.

The study of the work of the seven labourers proved to be highly illuminating. Firstly it was seldom that more than four of them were in the section at the same time, and it appeared that they did very little constructive work when they were in the picture. One of them spent about half his time helping one of the girls to wrap bearings, another sawdusted and swept a gangway twice in the same ten minutes, during which time no other person had walked along it. A labourer was seen putting Works Order forms into trays, the job of a clerk attached to the section, and a greaser was seen collecting empty trays for degreasing and refilling, this being one of the labourer's jobs. A detailed examination of the labourers' work was not performed, mainly because it would have taken too much time, and a knowledge of the actual job and the men is necessary for analysis of this sort.

This study was undoubtedly a success, and provided information that would have been very difficult to obtain by any other means. A strip of the film is shown in Fig. 17.

### 8.3. Short Tests on Area Studies

Three examples of these tests are shown in Figs. 18-20. The particular strips were chosen because they represent a gradual increase from a small area where a group of women are working rapidly as a team, to a large area where trolleys are moved slowly by three women.

All three films were taken in a canteen, and the frame interval used in the particular portion of the film that has been reproduced was one-second, in each case, so that a comparison can be made between the value of this film speed in each size of area.

It can be seen that in the case of the small area the film speed was not fast enough to study the movement of the operators properly, in the medium sized area it was adequate for the type of information one would require from the film, while in the large area a two second interval could equally well have been used.

In this manner information regarding the best film speed for particular area sizes was developed.

## 9. The Application of Memo-Motion to Team Studies

Team studies are a particular case of Area Study, but they are important enough to warrant description in a separate section of the report.

The definition of a Team Operation is as follows:- An operation involving more than one productive element, men or machines, whose actions are solely dependent upon those of the remainder of the team. Careful consideration will show that there are few cases in industry where men work together and come under this definition of a team, for example a group of navvies digging a hole may be paid as a team, but if one stopped working it would have no effect on the remainder. Examples of team work are a riveter and his mate, a rowing crew, or one man working a machine. In the latter case one of the productive elements is the man, and the other the machine he operates. There is no basic difference between a team consisting of a group of men, and one involving machines, and the classification of them together turns teamwork from something which is rarely found in industry, into one of the largest types of operation.

Team studies are an application in which Memo-Motion scores heavily over any other system of recording, since it is imperative that the study of each element of the team is synchronised with the study of the others. To achieve this with observers watching each element with stopwatches would be almost impossible, particularly if the team consisted of a large number of elements. With the camera it is simple, for each frame of the film records simultaneously the actions of each element of the team.

Teamwork is usually inefficient, for it is often difficult to balance the members of the team correctly. It is somewhat easier in the case of men and machine studies, because the machine has a definite operating time, and if the machine is automatic the amount of time the operator has to perform other duties, while the machine is running, can be accurately determined.

The study of team has been performed in the past by a laborious process of timing each operator independently and blending the operations together in chart form. Memo-Motion is simply a more convenient, and far more accurate, means of recording the information to produce such a chart. Because of the wealth of information available on the subject of analysing multi-activity charts, as Mundel describes them, it is not intended to discuss this aspect of team study here, but the method of constructing the chart from a film will be described, and reference made to a team study performed in a steel mill.



### 9.1. The Analysis of Team Study Films

Team study films are analysed by producing from them charts showing the relationship between the operations of the members of the team, a form of simo-chart in which the actions of individual members of the team are plotted against the same time base.

Before attempting the detail analysis of the film, the process sheet of the operation should be studied, or the observer familiarised with the operation in some other way, preferably by carefully watching it for some time. Projecting the film at as slow a speed as possible on a normal projector will help to acquaint the observer with the sequence of operation under study.

The first step in the construction of the chart is to decide upon the point in the cycle at which to start the analysis. This may not always coincide with the commencement of work on a new component, since this point may not be well defined. In the example described in Section 9.2. the analysis began at the point at which a machine was stopped, because it was easily recognised on the film.

Having decided upon the starting point, the procedure is simply to advance the film frame-by-frame, noting on the chart the actions of each member of the team in each frame. It is sometimes necessary to run the film backwards and forwards in order to find exactly when one action ends and another begins, but if the sequence of operations is known it is simple and fast to analyse a film.

As with simo-charts, a code is used to represent a given class of action, in effect a modified form of therblig. Mundel, and many other authors, suggest the use of different types of shading to represent different actions, but the limited experience gained during the work on this thesis indicated that a colour code is much quicker to use and more distinguishable, resulting in quicker analysis. The number of different classifications of action is usually small, and depends to some extent on the type of operation. In the example shown in Section 7.2 there were only four classifications, 'work', 'walk', 'position' and 'delay'. These four, plus on some occasions 'inspect', should cover most operations.

### 9.2. A Team Study in a Steel Mill

As an example of the application of Memo-Motion to Team studies, the actions of a team of three men operating a slitting machine in a cold mill were filmed and analysed.

Coiled strip came to the slitting machine from the

mills to be slit to the required width. The coils contained 1,500 feet of strip 12 inches wide, and were therefore heavy. The diameter of the coils was 3 feet.

The machine was well designed, having a turret to carry the coils being fed into and out of the machine, so that one coil could be loaded while another was being trimmed. A sketch of the layout appears in Fig. 21.

The process was to load the coils on to the turret at one side of the machine, and pass the strip through rotary cutters on to the turret at the other side of the machine. The turrets had expanding mandrels to grip the inside diameter of the coils, and because of their weight, a swinging crane was provided to lift them on and off the mandrels.

The cycle time was 3 minutes and 10 seconds, and a film speed of one frame per second was chosen. The ability of Memo-Motion to produce a film in the bad light of the steel mill was a good example of the value of the variable exposure time, since a 16 frame per second camera, with an exposure time only one third of that used during this study, would not have produced a film at all under the same conditions.

One page of the chart of the operation is shown in Fig. 22.

#### 9.2.1. Analysis of the Chart

A study of the chart showed the following significant details.-

- 1) The total delay time of the three men was 261 seconds, while the cycle time was 191 seconds.
- 2) The operations required before the machine can restart after finishing a coil are.- Turn turrets A and B, feed strip into the machine and round Turret A. In spite of the desirability to perform these operations as quickly as possible, one operator loaded turret B with a new coil while the machine was idle.

These two facts indicate that it should be possible to perform the operation in the same time using two operators instead of three. One essential factor to be considered in the analysis was that the idle time of the machine must not be enlarged, because of its high capital cost, and large orders for strip waiting.

### 9.2.2. Development of a New Method

Having seen that it would be possible to eliminate one man, a new chart was built up using the times for given operations from the previous chart as synthetics. The running time for the machine was constant, and hence the first step was to put this time on the chart and try to arrange the times for preparatory and supplementary operations to come within it. The operations required to enable the machine to start on a new coil after completing a cycle were then studied, and the two men were concentrated on them during the down time of the machine.

In the manner described above a new chart was prepared, and it showed that the operation could be performed by only two men, taking the same time as before for given operations, in a total time of 175 seconds, as opposed to the original time of 191 seconds with three men. This represents a saving of 40 per cent of the original labour content of the job.

The first page of the chart of the new procedure, is shown in Fig. 23.

The total time spent analysing the film and preparing the new method was four hours.

## 10. The Application of Memo-Motion to Utilisation Studies

Utilisation studies are that branch of Work Study concerned with the utilisation of men, or, more usually, machines. To make a continuous study of all the machines in a factory over a long enough period for accurate assessment of utilisation would be an impractical undertaking, but L.H.C. Tippett, of the Shirley Institute, devised in 1927 a system of making snap readings of the operations of textile machinery to determine its utilisation, based on statistics. He took these snap readings at random intervals so that cyclic occurrences did not affect the result, and this method has come to be known as Ratio Delay Study or Snap Reading Method.

Unfortunately this use of Memo-Motion in Utilisation Studies has not been fully covered in the time available, although a few short tests have been made.

In order to ascertain the ability of Memo-Motion equipment to determine Machine Utilisation it is only necessary to check its powers of recording whether a particular machine is running or not. This has been done in a jobbing machine shop, where it is impossible for a machine to be running without the operator attending it. In this application it is possible to

judge the condition of a machine, i.e. running or stationary, by the posture of the operator. The short strip of film in Fig. 24 shows this, but in a large automatic machine shop this would not be possible. This is a serious objection to the application of Memo-Motion to Utilisation Studies, but there are so many advantages in using the camera that it is worth trying to overcome it. There are two possible ways of doing this, one is to paint the chuck of the machine in stripes parallel to the axis of rotation, and the other to attach an indicator to the starting lever of the machine, so that it sticks up into the air when the machine is started. The latter of these two methods would be the best, since the chucks of many machines would be difficult to see, particularly when covered with a swarf guard.

The use of randomised time interval studies necessitates a machine for producing pulses at random intervals. The timing mechanism designed for this thesis will produce a limited pre-determined random interval, which would probably be sufficient for practical purposes, but a better machine could be quite easily constructed on the lines suggested in Section 5.3.2. If there is no cyclic part of the operation performed by the machines, it is not necessary to use random intervals between readings; it is pointed out in a paper by W. Kinniburgh and G. McTaggart that for non cyclic operations even intervals between observations will produce a more accurate answer than random intervals.

Utilisation Studies would be economic on film cost since 2,000 observations over a week would give ample accuracy, this being 500 feet of film.

Machines are generally either working or not working, there being no other classification of action. It is true that there may be a number of reasons why a machine is idle, and this the film will not reveal, but this is not a serious limitation to photographic techniques. Men, on the other hand, could be performing any number of different types of action, and so a Man Utilisation Study will have to cover more alternative actions. For this reason it is generally necessary to use more readings on Man studies than it is on Machine studies, as is shown on the chart in Fig. 1.

Memo-Motion applied to Utilisation Studies has disadvantages which are as follows.

- 1) It is sometimes difficult to decide from one frame exactly what type of action is occurring. This is only occasionally the case, and with a large number of snap readings it is justifiable to ignore any readings which are difficult to analyse.
- 2) The camera cannot cover so large an area as a human observer, or look round obstructions at men working behind them.



In one of the Area Studies described in Section 8, Jig Utilisation was referred to, and determined over a short period by filming continuously at 8 second intervals. It was mentioned that this was too short a frame interval for a practical utilisation study, but many area studies may well start off by filming over a short period at intervals of a few seconds, in order to ascertain the problem which may exist in the shop. Then if the utilisation during this short study was found to be particularly bad the decision could be made on performing a complete utilisation study over a period of at least a week. The preliminary study would reveal considerable useful information besides utilisation of equipment, and would thus not be wasted time and money.

#### 11. The Application of Memo-Motion to Work Measurement

Work Measurement is that branch of Work Study concerned with producing an allowed time for an operation. It is a measurement of human effectiveness, and its object is to achieve Improved Planning and Control, More Efficient Manning of Plant, Reliable indices for Labour Performance, Reliable bases for Labour Cost Control. and sound Incentive Schemes.

The function of measuring the quantity of work involved in a given operation requires the use of one of the following routine methods.-

- 1) Time Study, a procedure of timing and rating elements of the operation, to arrive at a normalised Time.
- 2) Synthesis, a system by which the time for an operation is built up from established element times. This is very useful in machine work, where an abundant supply of synthetic times for handling parts, starting machines, etc., is obtainable.
- 3) Analytical Estimating, used for operations that are of a non-repetitive nature, and the application of either of the other two techniques impractical. Analytical Estimating is applied by breaking the operation down into elements, applying a synthetic time to as many as possible, and estimating the time for the remainder.

The first of these techniques has been highly developed, and is beyond the scope of Memo-Motion, except when it is combined with the Method Study of an operation, and this case has been covered in Section 7.

The other two techniques, Synthesis and Analytical Estimating, are usually applied to operations of fairly long

duration, particularly in the case of Analytical Estimating, and they rely on the existence of standard times for common elements of work. In this function Memo-Motion can be of value, as time can be measured accurately by the camera, and more than one operation times at once.

The application of Synthesis is limited by the amount of synthetic data available, and the accumulation of new synthetics is expensive, particularly when they are concerned with lengthy operations, as may occur in maintenance work. Most modern factories have installed a planned maintenance scheme, so that there is a case for building up synthetic times for these operations if it can be done economically, and Memo-Motion techniques could be used to advantage for this purpose.

Some work has been done in America on these lines, and a one frame per second camera was used to establish Standard Performance Times for Fork Lift Trucks, see 'Modern Materials Handling' April, 1953. It would seem that there is here scope for extending the use of the camera into the fields of maintenance work, and all indirect labour operations, but it has not been possible to explore this possible field for the use of the Memo-Motion camera. The advantage of Memo-Motion in timing long operations is that it takes less time of a skilled observer, for a relatively unskilled man can set up the camera to film an operation, and it can be left all day. The timing of a long operation can be completed in a relatively short time, simply by counting frames.

Another possible use for the Memo-Motion camera is in the determination of Contingency Allowances for time studies. These are at present based largely on estimation, and the camera could record accurately how much time is taken for personal allowances, etc. Ratio Delay Study is applied to this already. The determination of Process Allowance is included under this heading, and these can be quite easily ascertained in a Team Study as described in Section 9 of this report.

## 12. Bibliography

- 1) 'Motion and Time Study', by Marvin E. Mundel. Chapter 13 refers to Memo-Motion Study.
- 2) 'Standard Performance Times for Fork Trucks', an article in Modern Materials Handling, December, 1953, describes how Memo-Motion was used to determine standard time data for fork lift trucks.
- 3) 'Memo-Motion Study Simplifies Work Analysis' by M.E. Mundel, an article in Factory, June 1949.

- 4) Industrial Management Society Clinic Proceedings for 1953 contains a report on a paper presented by A. Tseng, on Memo-Motion.
- 5) 'Why not try Area-Wide camera studies', Modern Materials Handling, December 1953, describes a form of Memo-Motion used to determine material flow in an aircraft factory.

-----

APPENDIX I

A.1. Description of Equipment used during the Research

The equipment used for the performing of Memo-Motion Studies falls into two main categories; the apparatus for producing the film, and the apparatus for analysing it.

A.1.1. The Equipment used for producing Memo-Motion Films  
(Fig. 25)

A Bolex H.16 cine-camera, manufactured by Paillard-Bolex Ltd., of Switzerland, formed the basis of the photographic apparatus used during the research. The camera was modified to take a single shot on receiving an electrical impulse from a timing mechanism capable of delivering impulses at a wide range of time intervals. The photographic unit was driven by six 6-volt dry batteries in series, giving a total of 36 volts.

A.1.1.1. The Modified Bolex H.16 Camera

The Bolex H.16 camera was chosen because of the excellent range of ancillary equipment available for it; lenses, filters, etc., and because it is the most commonly used camera for normal method study application in this country.

The modification to the camera consisted of attaching a solenoid operated ratchet to drive to an existing shaft on the camera normally used for driving the mechanism at 16 frames per second with an external electric motor.

The Bolex Camera has an internal clockwork motor drive which will take up to 18 feet of film at each winding. There is also a mechanism enabling single shots to be taken using this drive. Therefore, by using some form of actuation for the single shot button, it would be possible to make a Memo-Motion film at two frames per second of a job lasting six minutes, for a single winding of the camera.

However the time limitation, plus the fact that the internal mechanism was not considered robust enough to stand up

to continual usage, made it desirable to operate the camera by some other means, so the method used during the research was evolved.

#### A.1.1.2. The Timing Mechanism

The function of the Timing Mechanism is to supply the camera with electric pulses at the required intervals, and in designing it the following points had to be considered.-

- i) The time intervals must be accurate, so that an operation could be timed by counting frames.
- ii) The mechanism must be robust, and simple enough to repair on the spot should failure occur while on fieldwork. (This factor rules out the use of electronics.)
- iii) The range of intervals obtainable should be large, so that the research programme should not be limited by the apparatus.
- iv) It should be possible to obtain unevenly spaced intervals for Ratio Delay studies.
- v) The current consumption should be kept low.
- vi) The pulse length should be variable so that the current consumption of the camera is minimised by supplying a pulse of the minimum duration required to operate the Single-Shot Attachment.

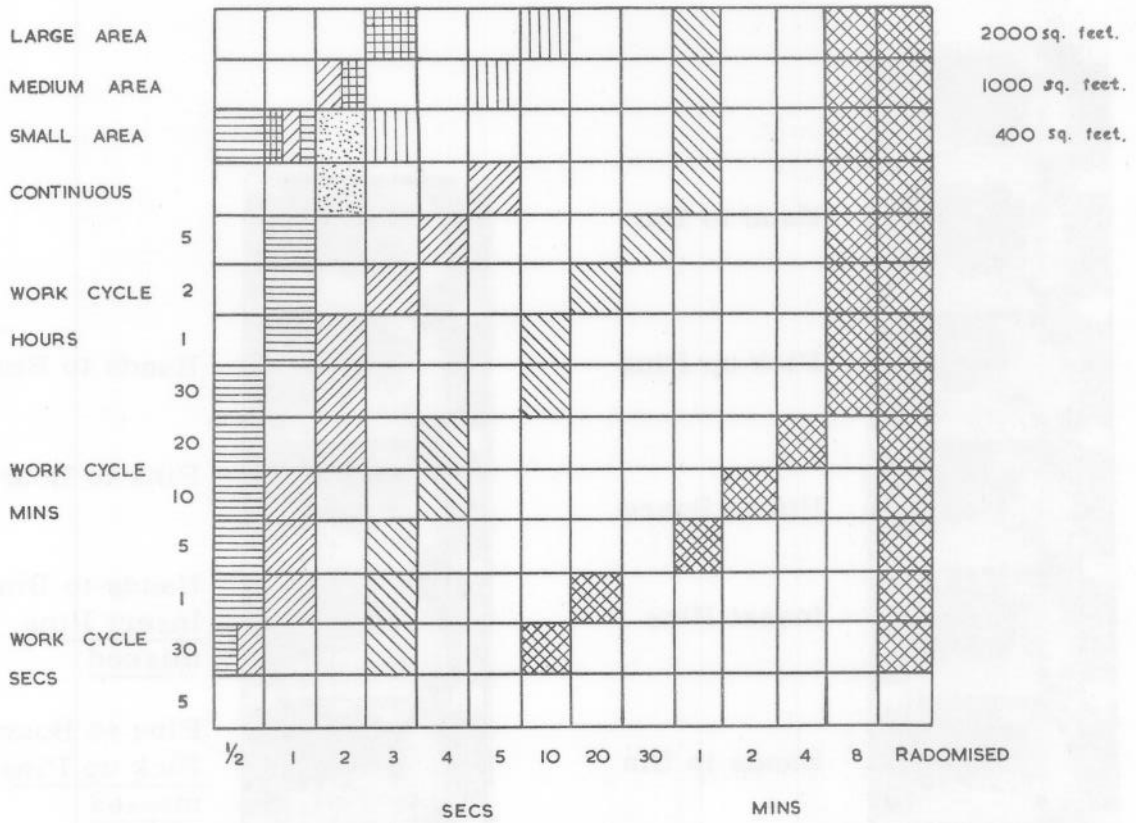
#### Pulse Intervals Obtainable from the Timing Mechanism

The following table gives the intervals at which pulses can be obtained from the Timing Mechanism. The figures marked \* are obtainable using Ratchets A and B only, and can be selected by switches. The rest necessitate the use of Ratchet C, and can only be selected by suitably wiring the Terminal Block.

It should be noted that in studies requiring the longer intervals Ratio Delay studies are more likely to be used than the normal regular spaced readings, so there is no necessity for the intervals to be finite multiples of a simple unit of time, i.e. a minute.



<u>Interval</u> <u>secs.</u>	<u>Interval</u> <u>mins.</u>
1	2.16
2	2.66 <sup>x</sup>
3	3.2
4	4.0 <sup>x</sup>
5	4.27
6	5.35
8	6.4
10	8.0 <sup>x</sup>
12	8.55
15	10.7
16	12.82
20	16.0
24	17.1
30	21.3
32	25.6
40	32
48	34.1
60 = 1 min.	42.6
64	51.1
80	64 = 1hr. 4 mins.
96	85.2 = 1hr. 25.2 mins.
120 = 2 min.	128 = 2hrs. 8 mins.
	256 = 4hrs. 16 mins.



**FRAME INTERVALS**  
**DIAGRAM SHOWING FRAME INTERVALS FOR INDIVIDUAL STUDIES**

LEGEND



MACRO - MOTION STUDIES, OR LONG CYCLE MICRO-MOTION STUDIES



DETAILS OF PROCESS, e. g. SEQUENCE OF ASSEMBLY TIME STANDARDS FOR WORK MEASUREMENTS.



OPERATOR MOVEMENT OVER AREA



PROPORTION OF TIME SPENT BY OPERATORS ON GIVEN TYPES OF WORK



SHOP LAYOUT, MATERIAL FLOW



MAN AND MACHINE UTILISATION



WORKPLACE LAYOUT.

**FIG. I.**



Hand to Bin

Pick up Pins

Pin to Board

Insert Pins

Hands to Bin

Pick up Pins

Pins to Board

Insert Pins

Hands to Bin



Hands to Bin

Pins to Board

Hands to Bin  
Insert Pins  
missed

Pins to Board  
Pick up Pins  
missed

Hands to Board  
Insert Pins  
missed

Insert Pins

Pins to Board  
Whole Operation  
missed

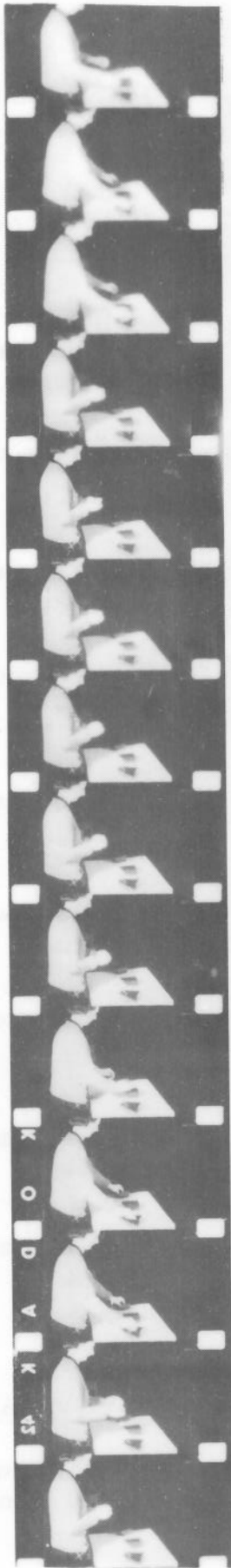
Hands to Bin

$\frac{1}{2}$  sec. Intervals

1 sec. Intervals

Figs. 2 & 3. Loading Pin Board.

These two strips of Film show that the operation is covered adequately by the  $\frac{1}{2}$  second film, but not the 1 second, where some parts of the cycle are missed completely.



$\frac{1}{2}$  sec. Intervals

Pick up Nut  
and Bolt

Nut and Bolt  
to Centre

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

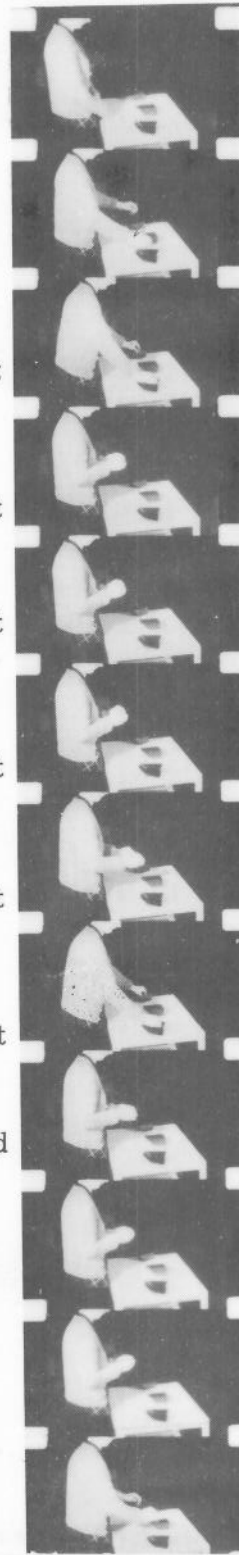
Place Nut and  
Bolt in Bin

Pick up new  
Nut and Bolt

Pick up new  
Nut and Bolt

Nut and Bolt  
to Centre

Assemble Nut  
and Bolt



Pick up Nut and  
Bolt

Pick up Nut and  
Bolt

Assemble Nut  
and Bolt

Assemble Nut  
and Bolt

Assemble Nut and  
Bolt

Nut and Bolt to  
Bin

Place Nut and  
Bolt missed

Pick up new  
Nut and Bolt

Assemble Nut  
and Bolt

1 sec. Intervals

Figs. 4&5. Assembly of Nut & Bolt





Hand to Blocks

Blocks to Centre

Blocks to Back

Hands to Blocks

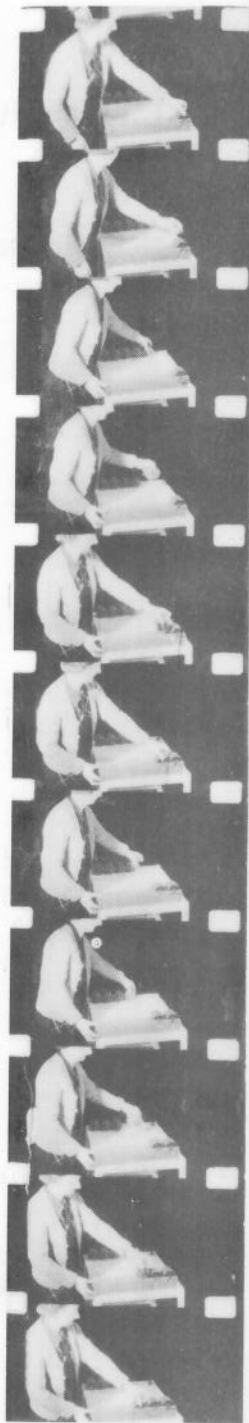
Blocks to Centre

Blocks to Back

Blocks to Back

Hands to Blocks

Blocks to Centre



Place Armature  
in rack

Hand to new  
Armature

Pick up new  
Armature

Armature to  
Rack

Place Armature  
in Rack

Place Armature  
in Rack

Hand to new  
Armature

Pick up new  
Armature

Armature to  
Rack

Place Armature  
in Rack

Place Armature  
in Rack

Fig. 6. Moving Blocks.

Fig. 7. Moving Armatures

These strips of film illustrate the accuracy with which even fast movements are recorded by the  $\frac{1}{2}$  second interval films.



Left Hand to Drill Handle

Lower Drill Chuck

Lower Drill Chuck

Drill Plate

Drill Plate

Drill Plate

Lift Drill Chuck

Lift Drill Chuck, lift plate off  
table with right hand.

Lower plate to bench

Place plate on bench

Grasp new plate

Lift new plate to drill table

Place plate on table, lower drill

Lower drill chuck

$\frac{1}{2}$  sec. Intervals.

Fig. 8 Drilling Plate

Fig. 5. Drying Plate

Lower shell chuck

Place plate on table, lower shell

Fill new plate to shell table

Change new plate

Place plate on bench

Lower plate to bench

Use shell chuck, the plate of  
table with right hand

Use shell chuck

Over plate

Over plate

Over plate

Lower shell chuck

Lower shell chuck

Left hand to shell handle



Fig. 6. Drying Plate

SHEET No. 1 of 8.  
 OPERATION. ASSEMBLY OF SPRAY GUN.  
 PART NAME. B.E.N. TYPE W.H.  
 OPERATORS NAME & No.

FILM No. I.  
 CHART BY.  
 DATE. MARCH 1954.  
 OPERATION No. 1000.  
 PART No. W.H.

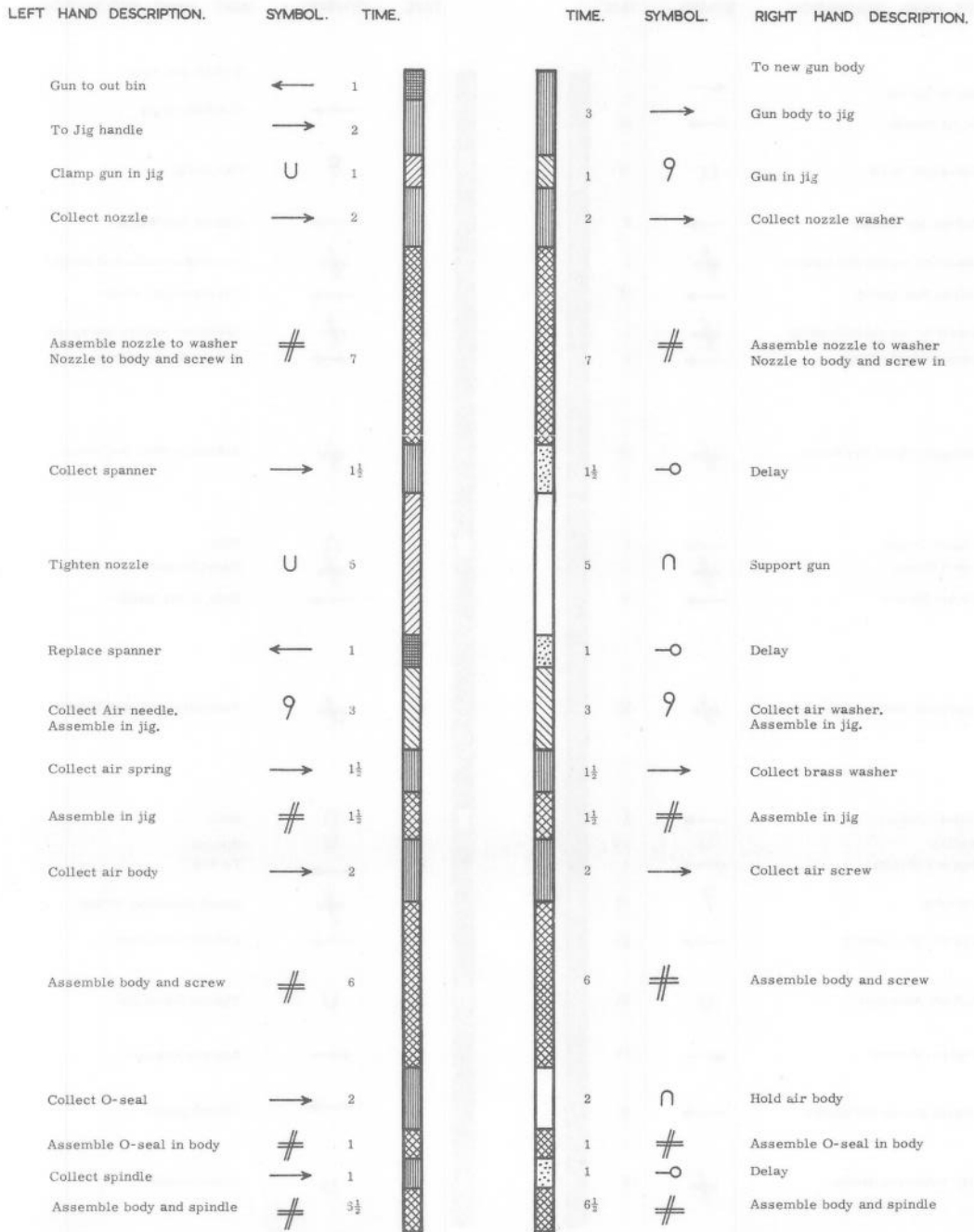


FIG. 9



SHEET No. 1 of 6

OPERATION. ASSEMBLY OF SPRAY GUN  
NEW METHOD.

PART NAME. B.E.N. TYPE WH.

OPERATORS NAME & No.

FILM No. 2.

CHART BY

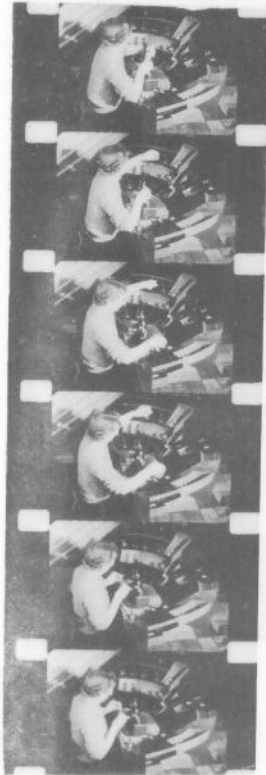
DATE. APRIL. 1954.

OPERATION No.

PART No.

LEFT HAND DESCRIPTION.	SYMBOL.	TIME.	TIME.	SYMBOL.	RIGHT HAND DESCRIPTION.
Gun to out bin	←	1			To new gun body
To Jig Handle	→	1½	2½	→	Gun body to jig
Clamp gun in jig	U	1½	1½	9	Gun in Jig
Collect Air Needle	→	2	2	→	Collect Air Washer
Assemble needle and washer	#	1	1	#	Assemble needle and washer
Collect Air spring	→	1½	1½	→	Collect brass washer
Assemble needle and spring	#	1	1	#	Assemble washer and spring
Collect Needle Body	→	1	1	→	Collect Needle Screw
Assemble Body and Screw	#	5½	5½	#	Assemble Body and Screw
Collect O-seal	→	1	1	→	Hold
Insert O-seal	#	1	1	#	Insert O-seal
To Air Needle	→	1	1	→	Body to Air Needle
Assemble Body and Needle	#	6½	6½	#	Assemble Body and Needle
Collect Shellac	→	1	1	→	Hold
Shellac	U	½	½	U	Shellac
Replace Shellac	←	1	1½	→	To Gun
Turn Jig	9	1½	1	#	Insert Assembly in Gun
Collect Box Spanner	→	1½	1½	→	Collect nut runner
Tighten Assembly	U	2½	2½	U	Tighten Assembly
Replace spanner	←	1½	1½	←	Replace spanner
Collect sleeve and needle	→	2½	2	→	Collect guide
Jig, sleeve on needle	#	10	3	U	Clamp needle

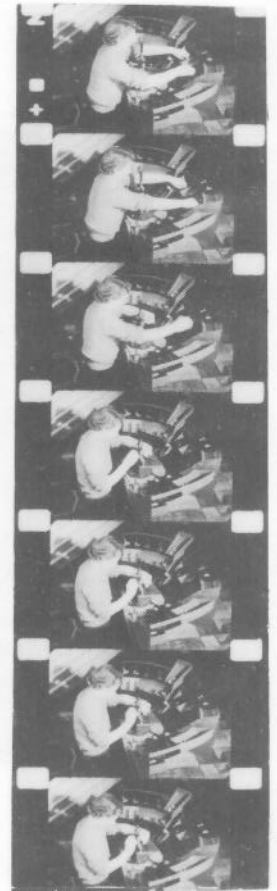
FIG. 10.



11A.



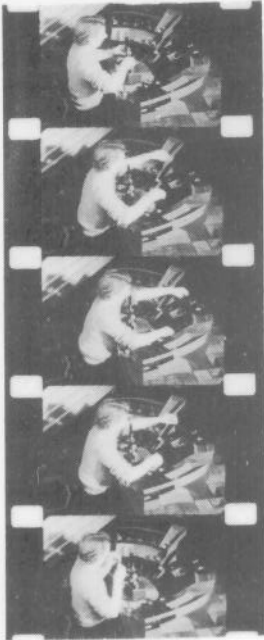
11B.



12A

Figs. 11 - 12A. Bad Movements during Assembly.

- 11A. Bad movement due to incorrect positioning of components in bins.
- 11B. Body twist and stretching during the picking up of a pneumatic nut-runner. Overcome by repositioning the nut-runner and revolving the jig through 45 degrees before screwing in the sirvalves.
- 12A. Well balanced movement, collecting components from bins, but the bins are too far back, causing the operator to stretch, and nearly hit her chin on the handle of the gun.



12B.



13A.



13B.

Figs. 12B. - 13. Bad Movements during Assembly.

12B. Out of balance movement due to incorrect placing of the shellac brush. This was overcome by re-positioning the parts.

13A. Bad body twisting, due to difficulty of screwing trigger pad to trigger. Cured by chamfering the threads of the screws.

13B. These frames show an out of balance movement of the left and right hands, due to lack of synchronisation of the operations of the two hands.



1 sec. Intervals.

Fig. 14. Memo-Motion Film of Aircraft Aileron Assembly.

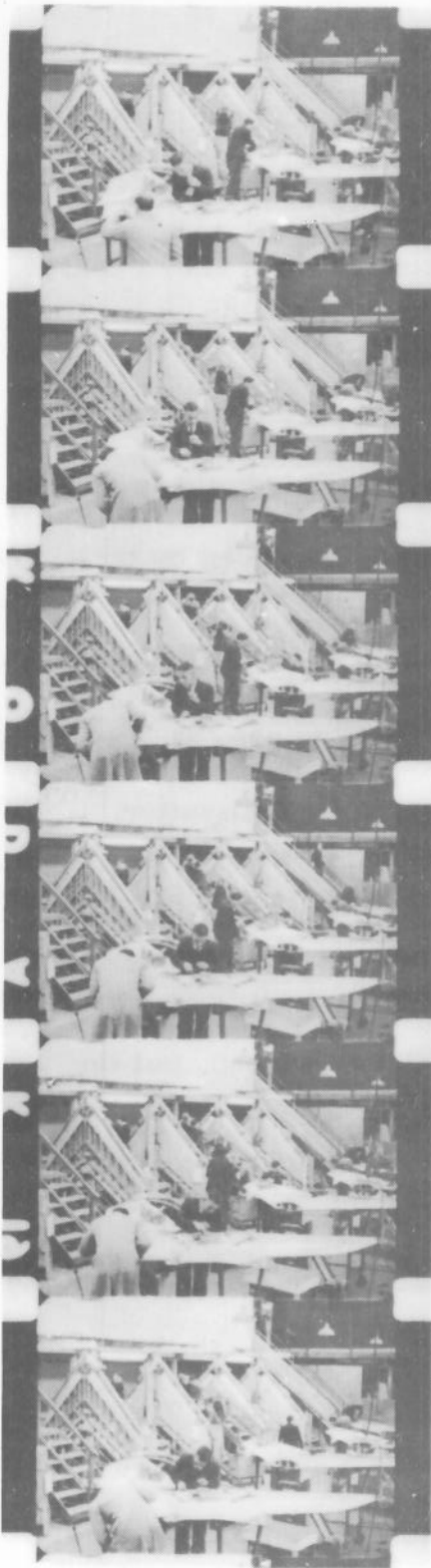
This strip of film shows that it is only possible to study closely the actions of the two operators in the foreground, those at the back being obscured by their jigs.

However it is possible to see if the jigs are in use, and hence determine Jig Utilisation.

It is obviously much easier to examine the film when projected onto a large screen, but the general congestion can be seen, and the cockpit canopy which should not have been seen in the section.

This is one sequence when the male operator was helping the girl.





8 sec. Intervals.

Note that in this sequence operators can be seen working in three of the jigs.

The operator in the dark jacket working on the tailplane in the foreground is the one referred to in the text as taking far too long to attach a cover plate.

Fig. 15. Area Study on the Assembly of Aircraft Tailplanes.



This strip of film shows the assembly jig for aircraft wings. The two riveters can be seen working on the right hand wing, and of the other pair, one is searching in a tool box, and the other is walking from the inside of the wing to the outside. The general chaos of the work area can be appreciated.

1 sec. Intervals.

Fig. 16. Aircraft Wing Assembly Film Strip



Trays containing unwrapped bearings

Labourer putting Works Order Forms into trays of bearings

Girl reaching for new tray of bearings

Girls actually studied in detail waiting for new job

Greaser, talking to girls

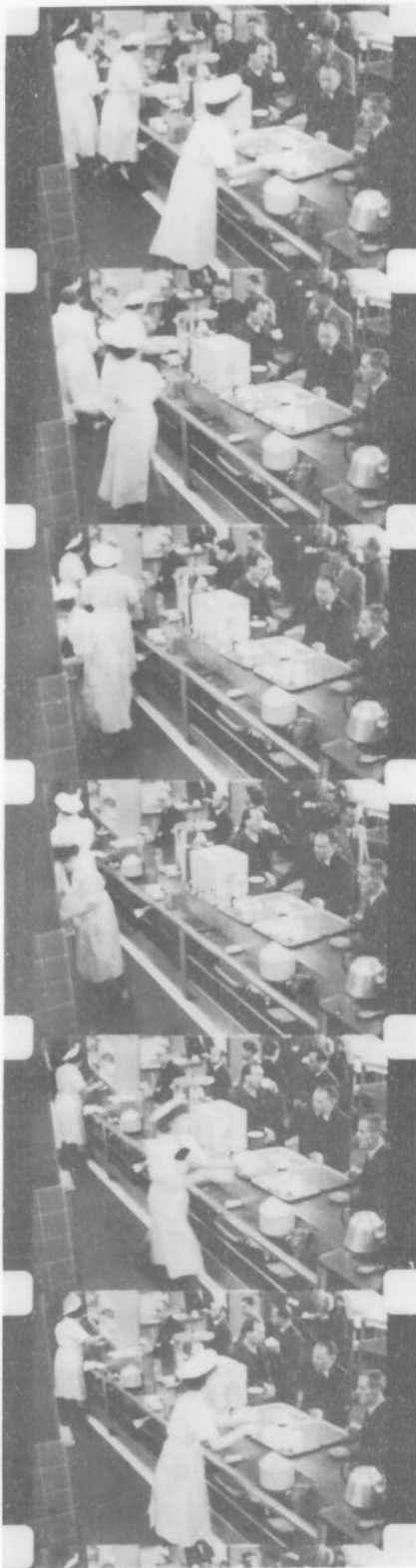
1 sec. Intervals

Fig. 17 Memo-Motion Study of Wrapping Department.



This strip of film shows a team of women working very rapidly on washing plate spacing rings in a canteen. The action is very fast, rings being passed from one girl to another for washing and drying. This is virtually a micromotion study on a group of operators, and the frame interval was one second. This is just insufficient to enable the movements to be followed properly, although careful study would permit a Simo-Chart to be produced. A film speed of two frames per second would be better for an operation containing movements as fast as these.

Fig. 18. Area Study Test on a Small Group of Operators, in a Small Area.

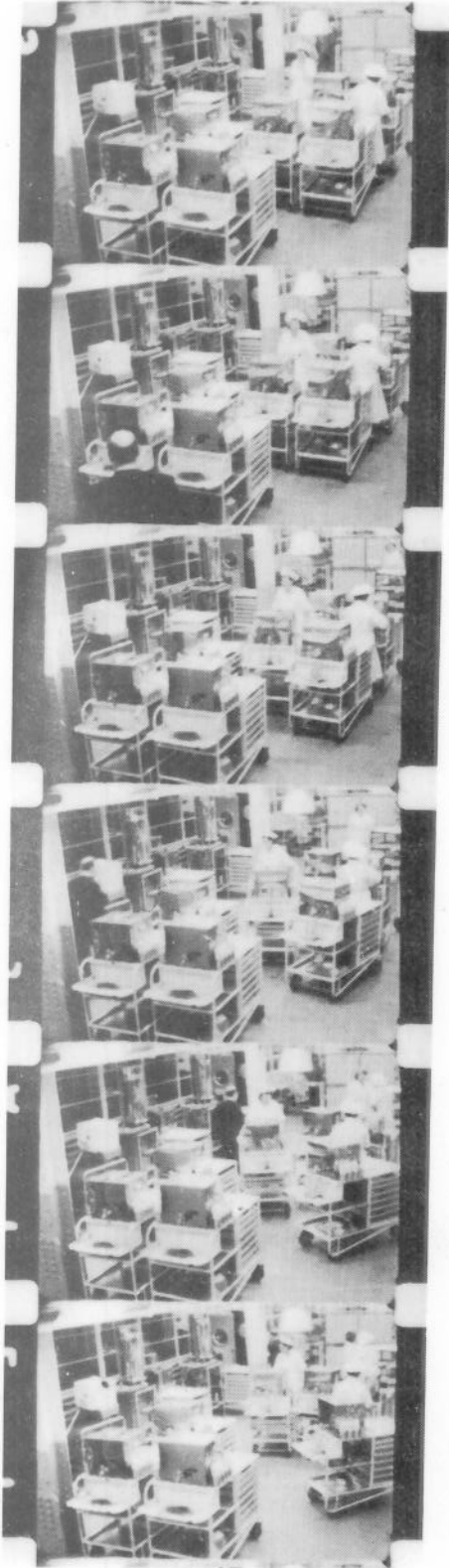


The Area covered by this strip of film is about twice that of the last. The information one would require from a study of this operation, serving food over a counter, would concern the movement over the area by the women, for the purpose of collecting dishes etc.

It can be seen that the frame interval used, one second, was adequate for this purpose, but that two second intervals would cause some part of the movements to be missed.

Fig. 19. Area Study Test on a Medium Sized Area.





The Area shown in this strip of film is larger than either of the previous two. It is the Tea Depot of a large factory, and the trolleys used to convey the urns of tea to the various departments can be seen. In this area the trolleys are loaded with cakes by moving them to a rack previously loaded by the bakers, and the urns filled with tea by moving them under the boilers which can be seen on the left background of the picture. Thus it is mainly a study of the movement of these trolleys, and the one second interval used between the frames is wasteful in film, for two second intervals would have yielded the same information.

Fig. 20. Area Study in a Large Area.

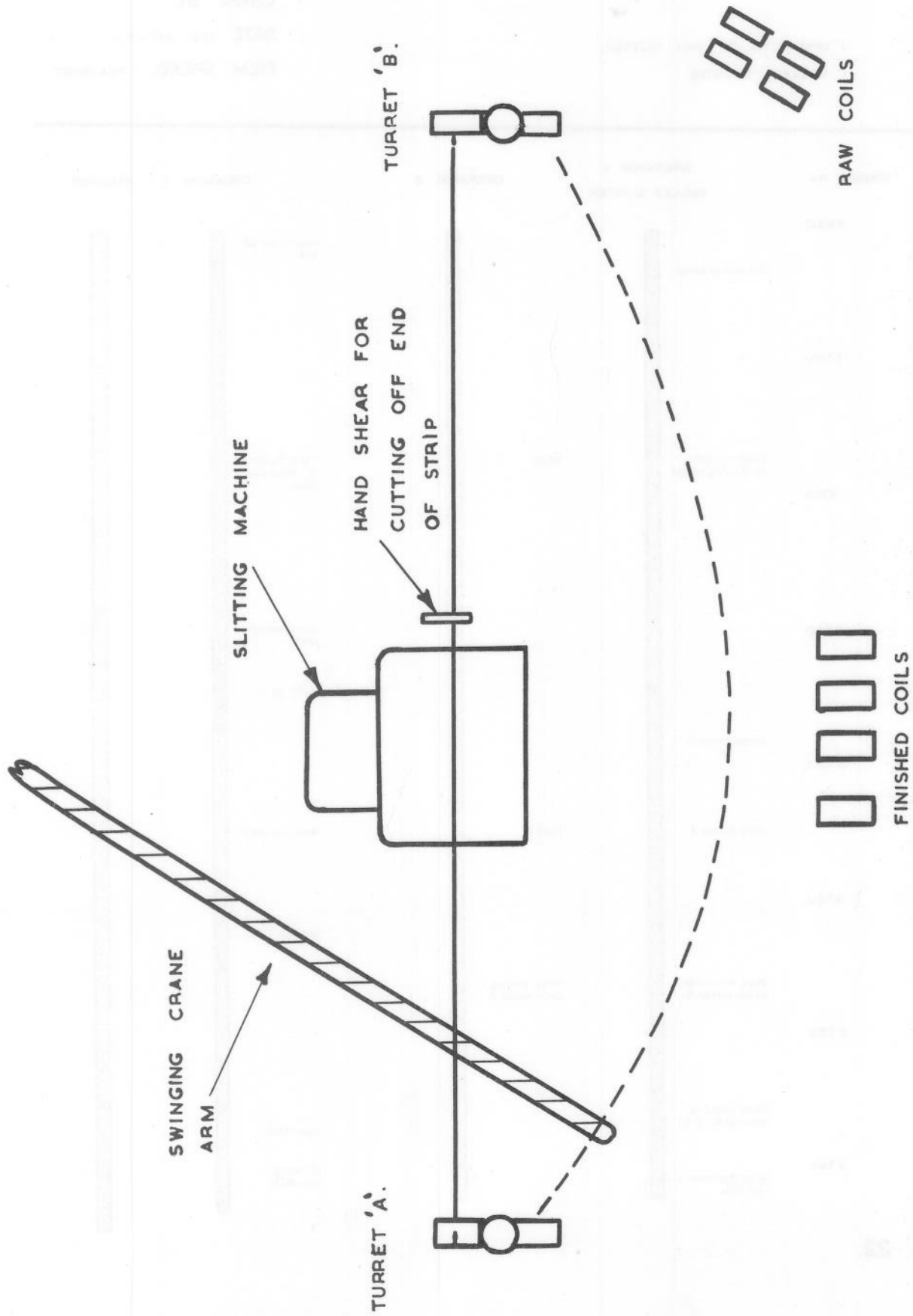


FIG. 21. SKETCH OF SLITTING AREA. SCALE 1" REPS 5" APPROX.

SHEET No. 1. OF 3.

OPERATION: SLITTING STEEL STRIP - ORIGINAL

3 OPERATORS ON No. 1. SLITTER.

1 SKILLED, 2 MATES

STUDY No. 161.

FILM No. 6.

CHART BY.

DATE FEB. 19<sup>TH</sup> 1954

FILM SPEED. 1 FRAME/SEC.

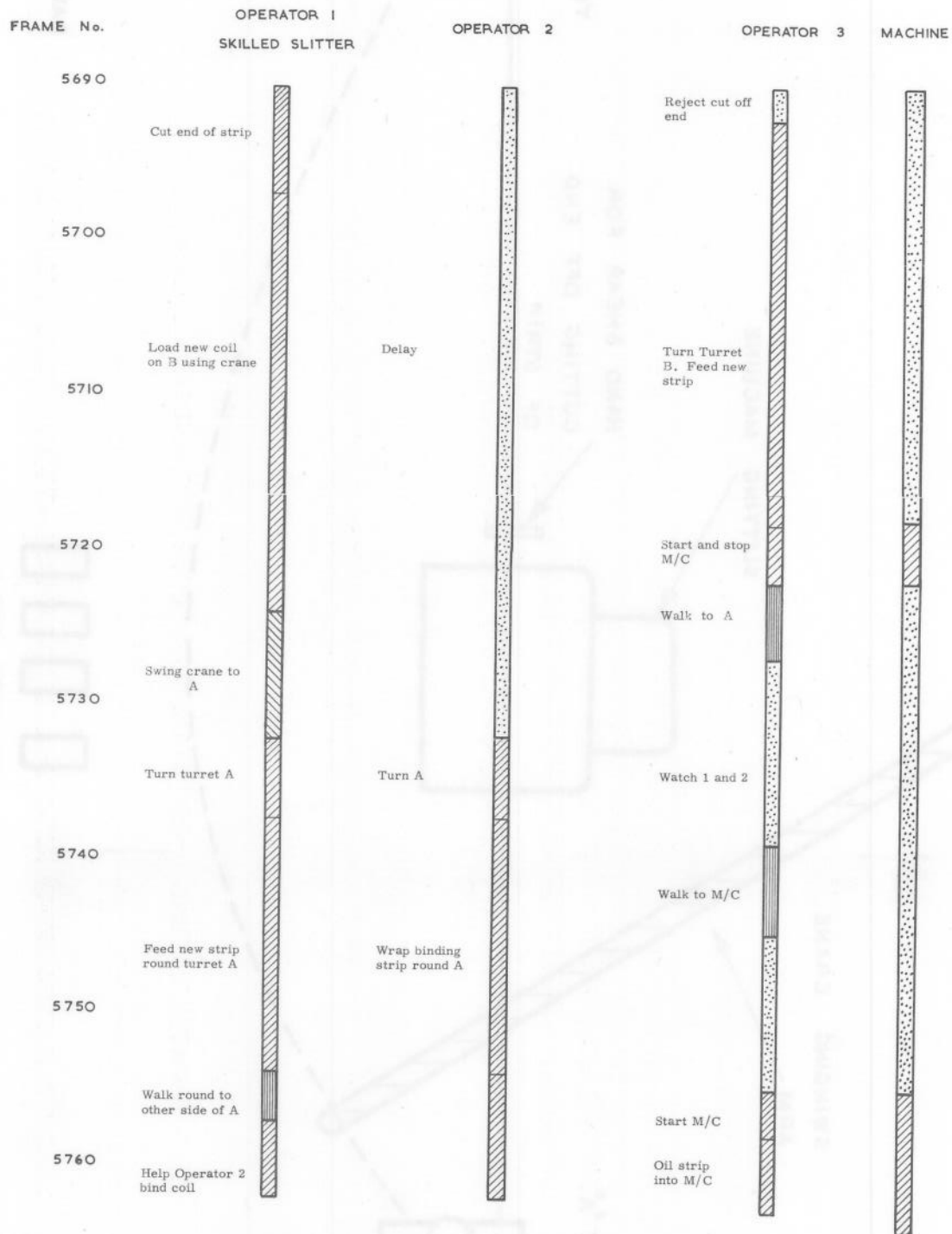


FIG. 22.

SHEET No 1 OF 3.

OPERATION SLITTING STEEL STRIP  
PROPOSED METHOD

2 OPERATER ON No 1. SLITTER  
1 SKILLED & 1 MATE.

STUDY No. 161/A

FILM No.

CHART BY.

DATE. FEB. 20<sup>TH</sup> 1954.

FILM SPEED.

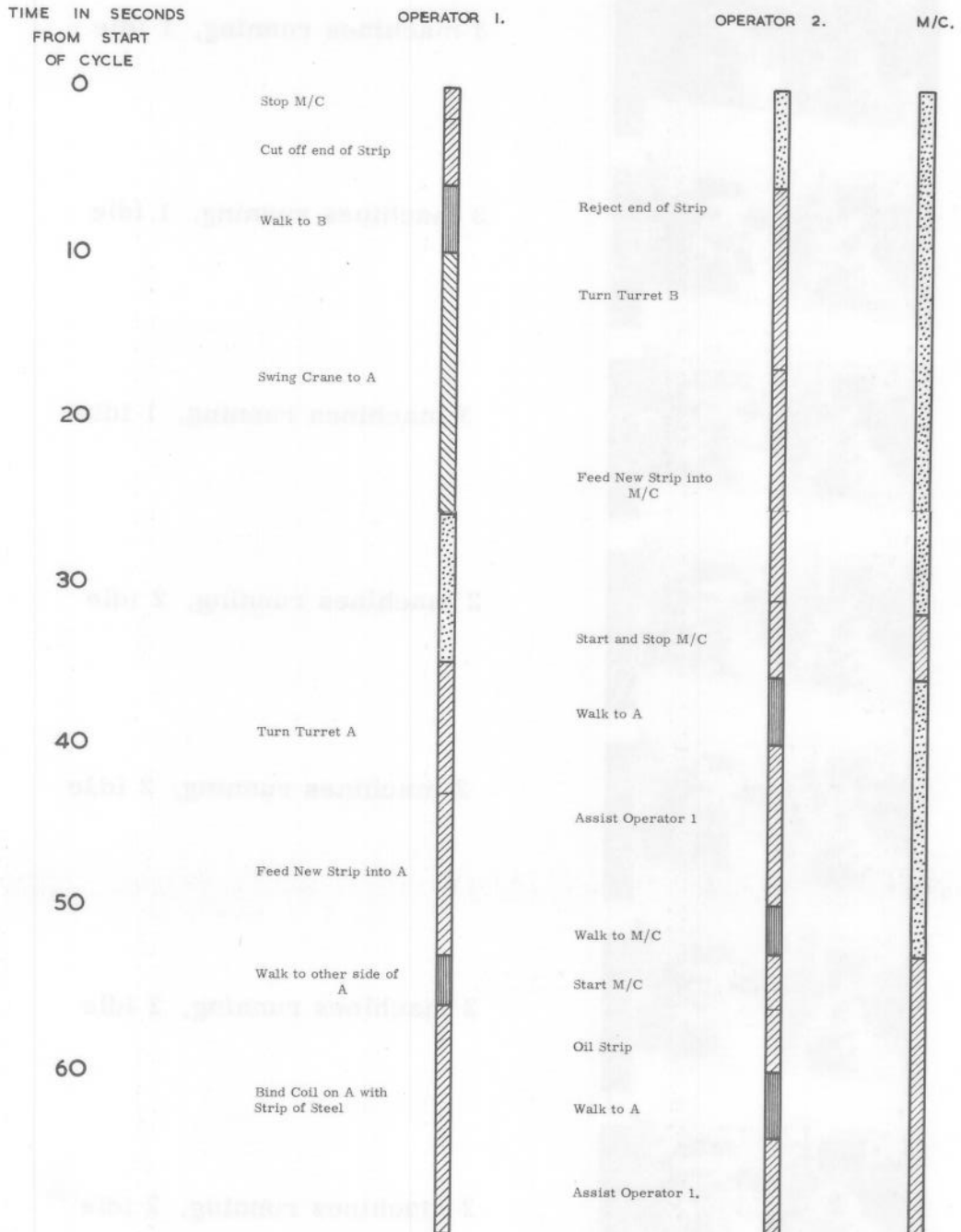
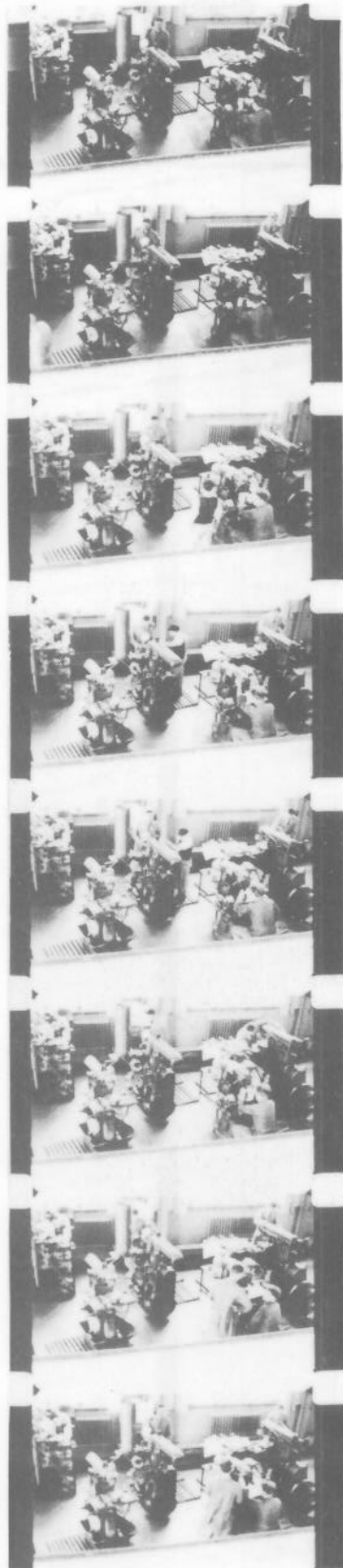


FIG. 23.



3 machines running, 1 idle

3 machines running, 1 idle

3 machines running, 1 idle

3 machines running, 1 idle

2 machines running, 2 idle

2 machines running, 2 idle

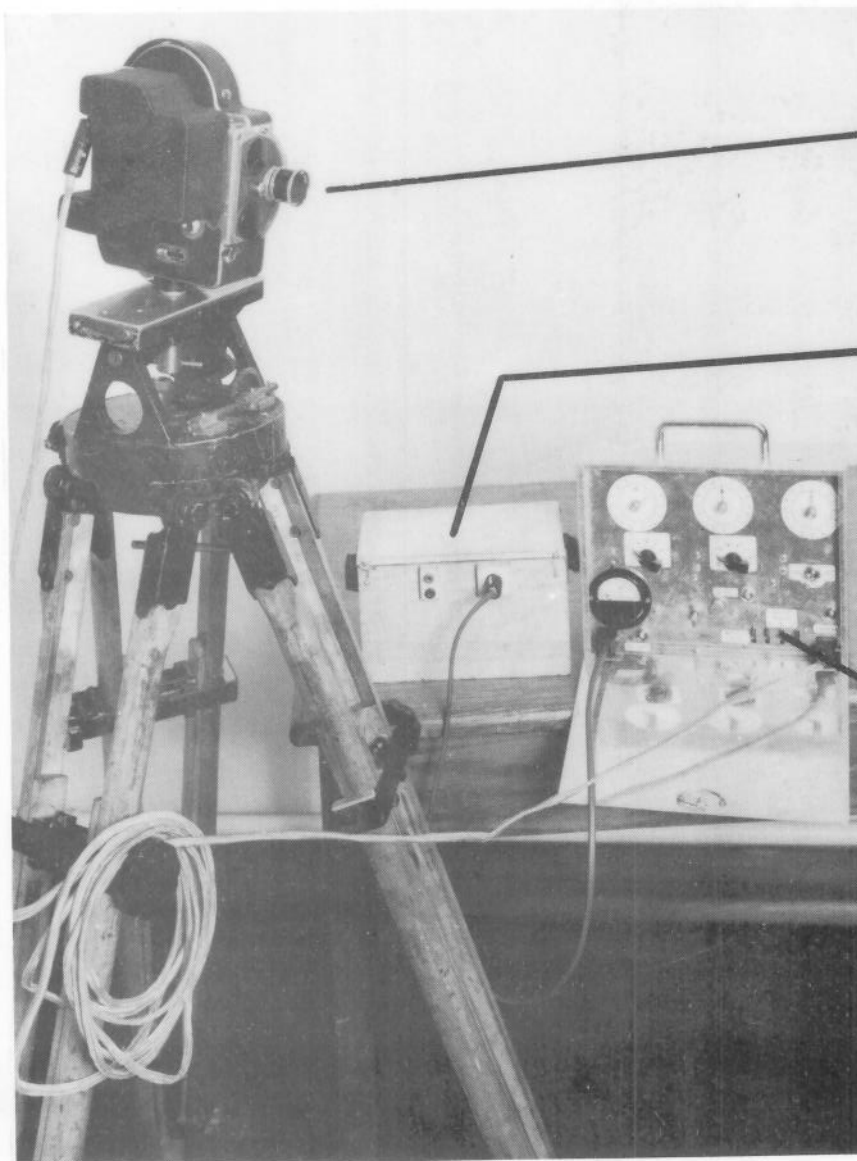
2 machines running, 2 idle

2 machines running, 2 idle

15 sec. intervals

Fig. 24. Machine Utilisation Study.





Camera with  
Attachment

Battery Box

Timing Unit

Fig. 25. Complete Photographic Apparatus