

THE COLLEGE OF AERONAUTICS
CRANFIELD



THE CRANFIELD ERGONOMICS LABORATORY

by

W. T. Singleton

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CRANFIELD

The Cranfield
Ergonomics Laboratory

- by -

*W. T. Singleton, M.A.



* Lecturer in the Department of Production and Industrial Administration

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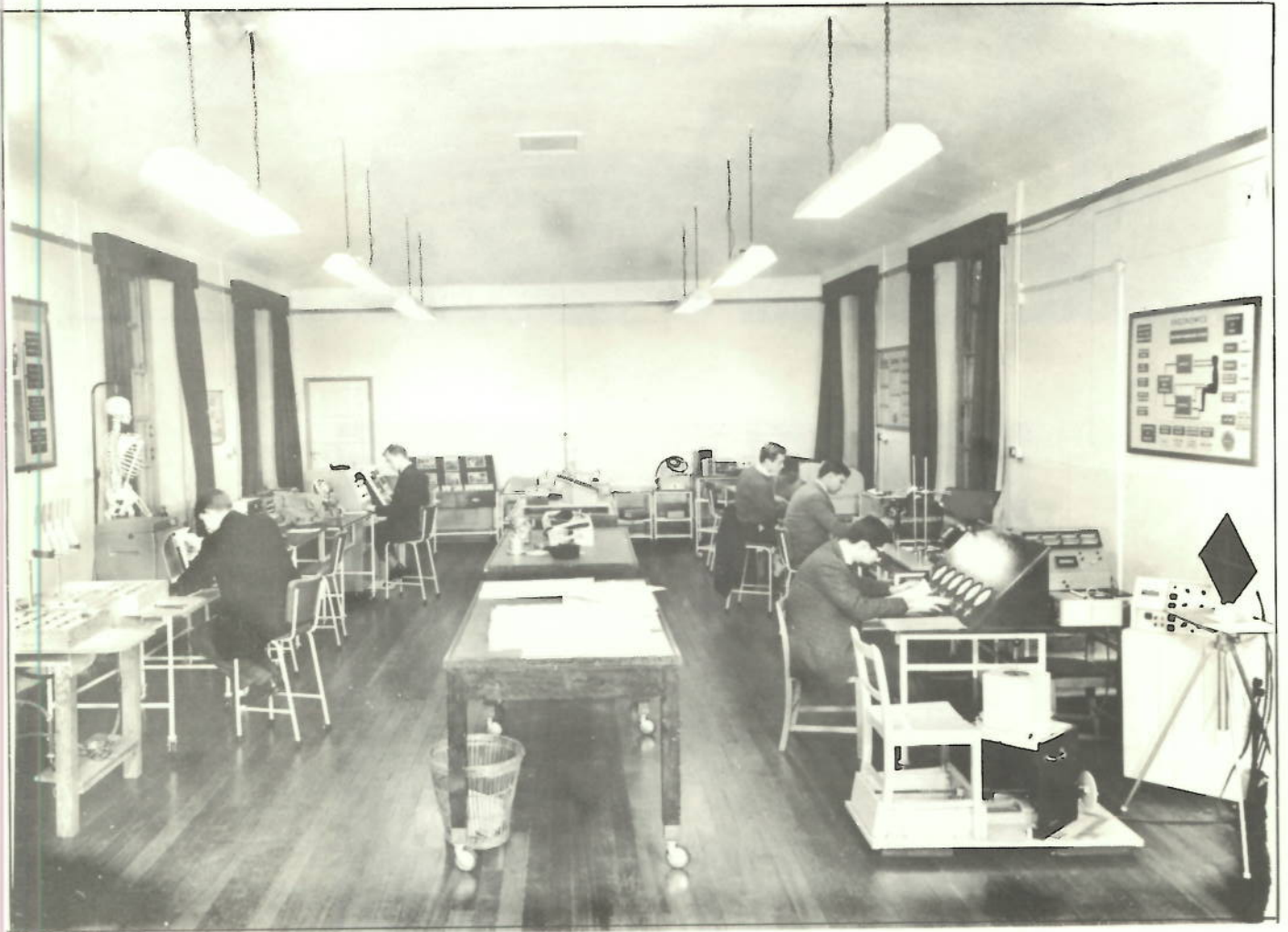
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Introduction

Ergonomics is a cross discipline between the human sciences and engineering. It is concerned with the design of man/machine systems, using the characteristics of the operator as the frame of reference.

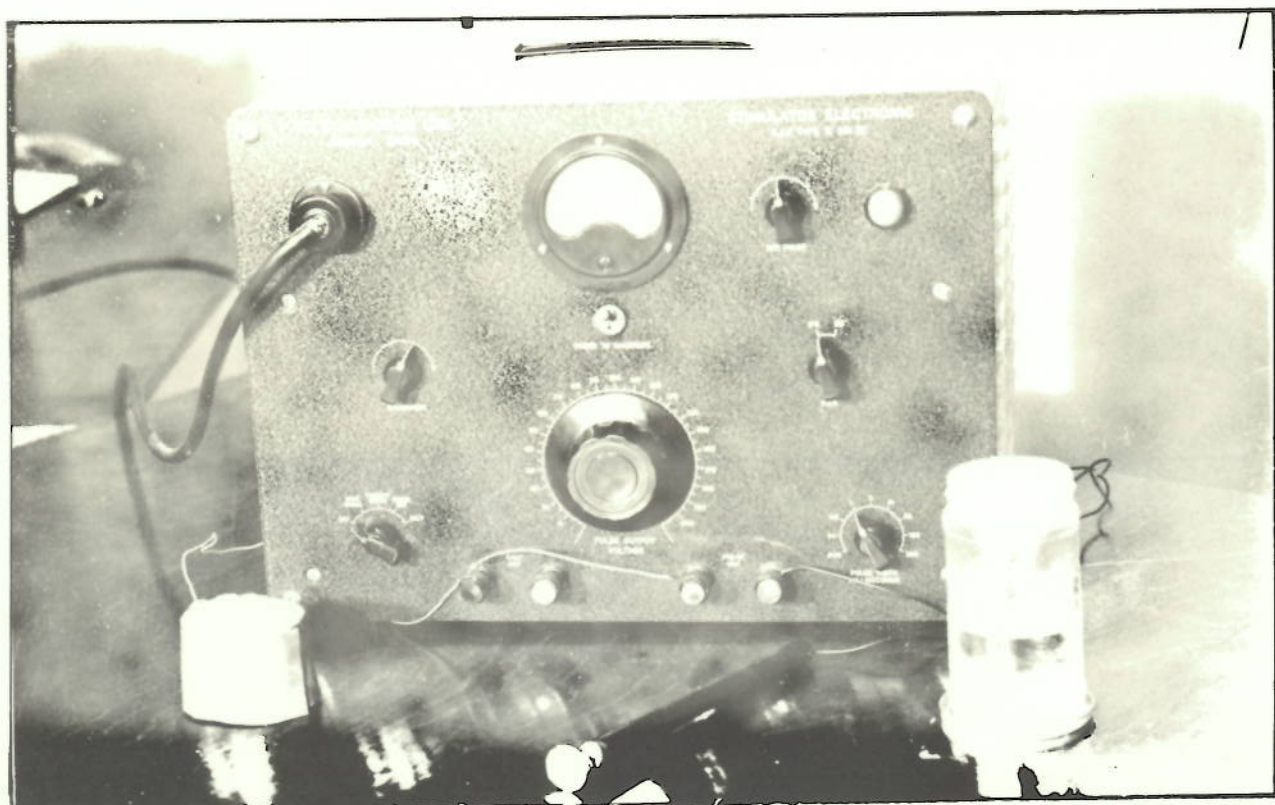
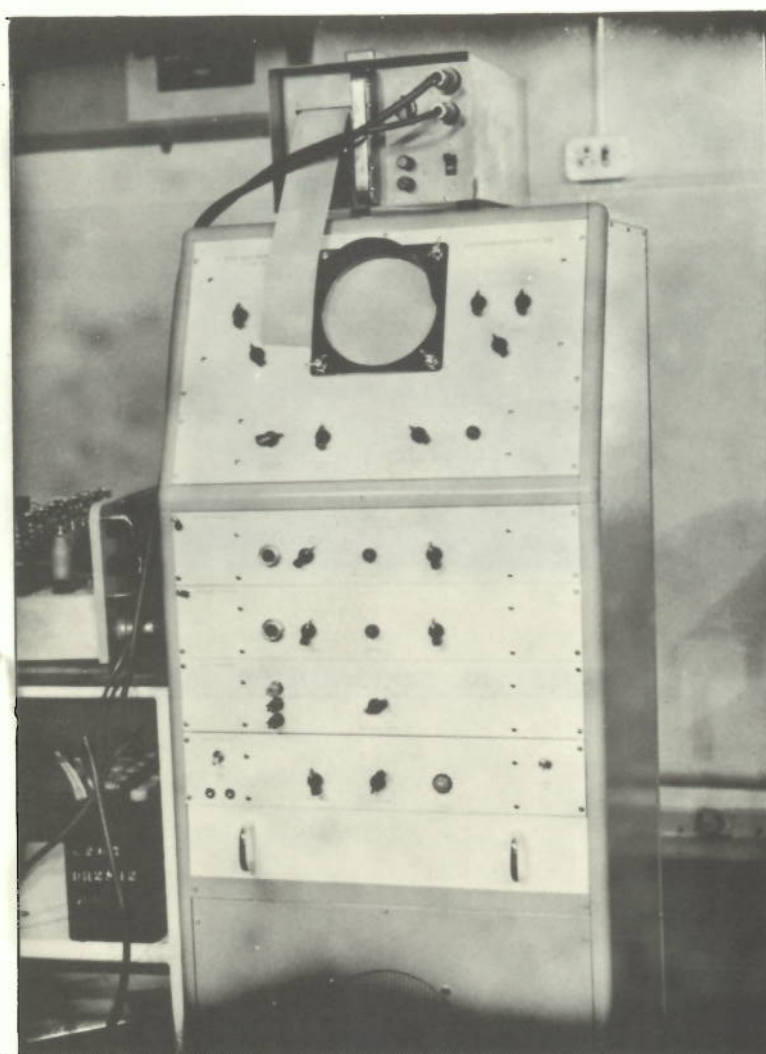
The state of our technology is now such that almost any purposeful activity involves a man and a machine operating together. Thus the basic working or fighting unit is the man/machine system and the efficiency of the system is dependent on the weakest link. Until recently this has usually been within the machine, but we have reached the stage when it may now be in the man, or between the man and the machine. It thus becomes necessary for the engineering designer to build his "hardware" to suit the human operator as well as to meet the need which the system is required to fulfil. To achieve this objective the designer requires data and advice on human performance. The provision of this information is a difficult task because of the complexity and variability of human performance. There are, at present, few laws of human behaviour which can take quantitative forms, and to obtain numerical information it is often necessary to resort to direct manipulation of the relevant variables. Fortunately, there is a considerable body of knowledge and experience on the measurement of human performance which has been developed by psychologists, physiologists, anatomists and work study practitioners. Thus, ergonomics is based on statistically controlled experimentation and, in common with other experimental sciences, it can only be taught effectively by a combination of lectures and laboratory periods.

The objective of the Cranfield Ergonomics Laboratory is to provide these facilities so that students can acquire a knowledge of experimental techniques and of the variables which they are manipulating. The students may be specialists in this field or may be engineers from other fields who wish to acquire some knowledge of the subject. The formal experiments require at least two students, one to act as a subject and the other as observer. Each experiment takes two or three hours to perform, and a similar period is required to read appropriate reference material and write a report.



GENERAL VIEW OF THE ERGONOMICS LABORATORY





FUNCTIONAL ANATOMY 1.

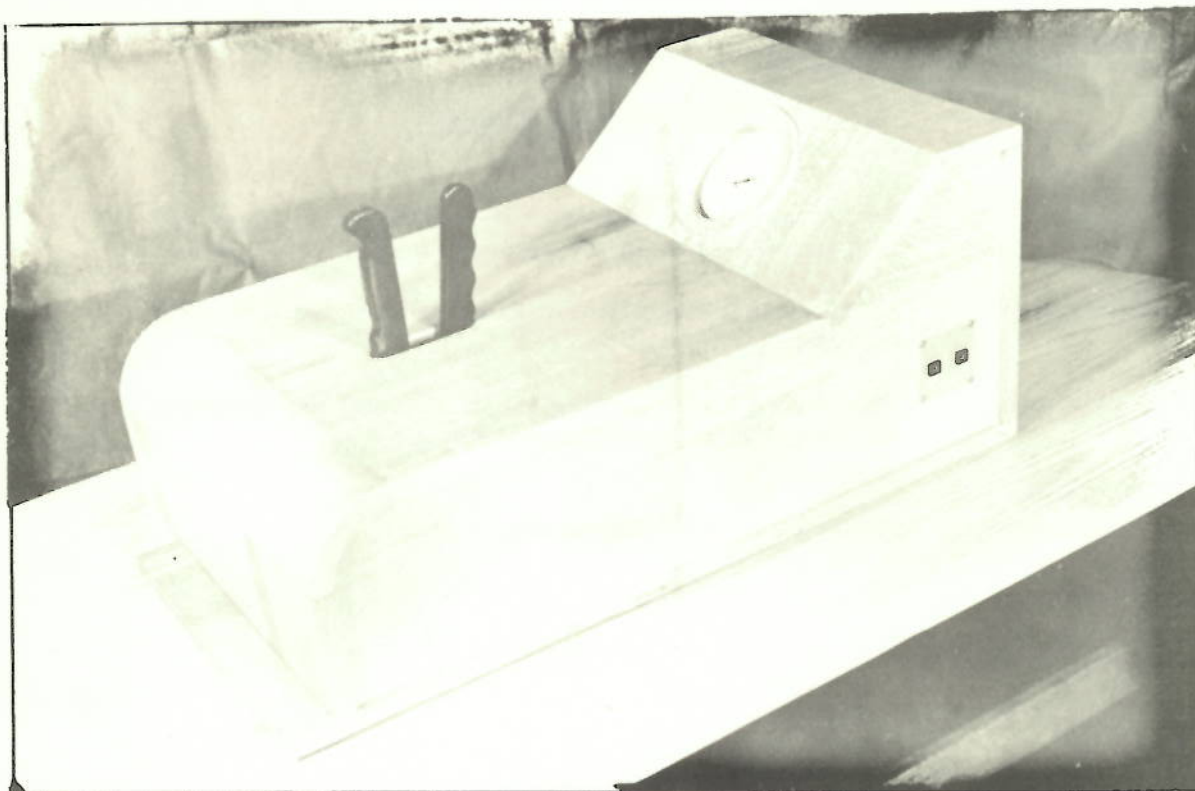
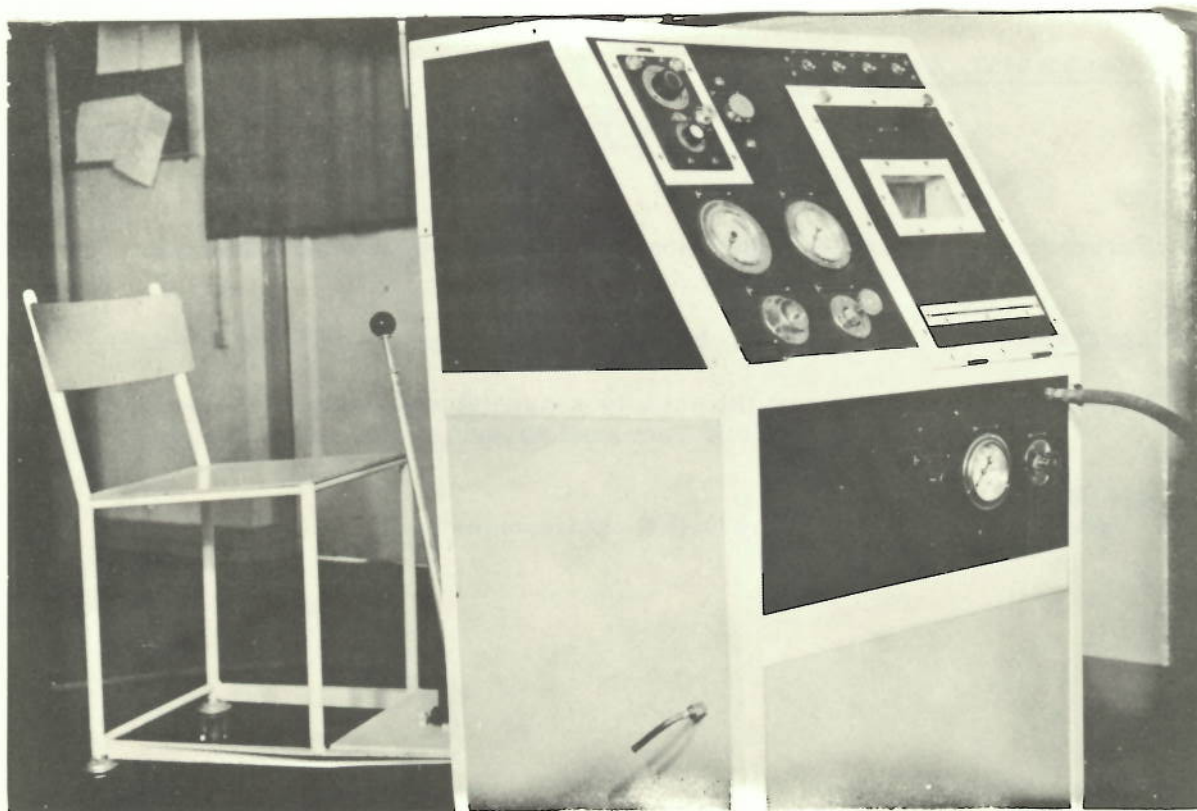
MUSCLE STIMULATOR

Purpose:	To locate the positions of different muscle groups and to illustrate some of the principles of muscle action.
Apparatus:	An electrical stimulator with variable pulse intensity, frequency and duration.
Experiment:	The student examines the effect of the above variables on the action of his own muscles.
Availability of apparatus:	Produced by S.S. Electronics Ltd.

FUNCTIONAL ANATOMY 2.

ELECTROMYOGRAPH

Purpose:	To detect and record electrical activity associated with muscle action.
Apparatus:	Two channel electromyograph with vacuum electrodes.
Experiment:	To record the activity of agonist and antagonist muscle groups for different hand pressures and arm movements.
Availability of apparatus:	Produced by G.H.S. Electronics Ltd.



FUNCTIONAL ANATOMY 3.

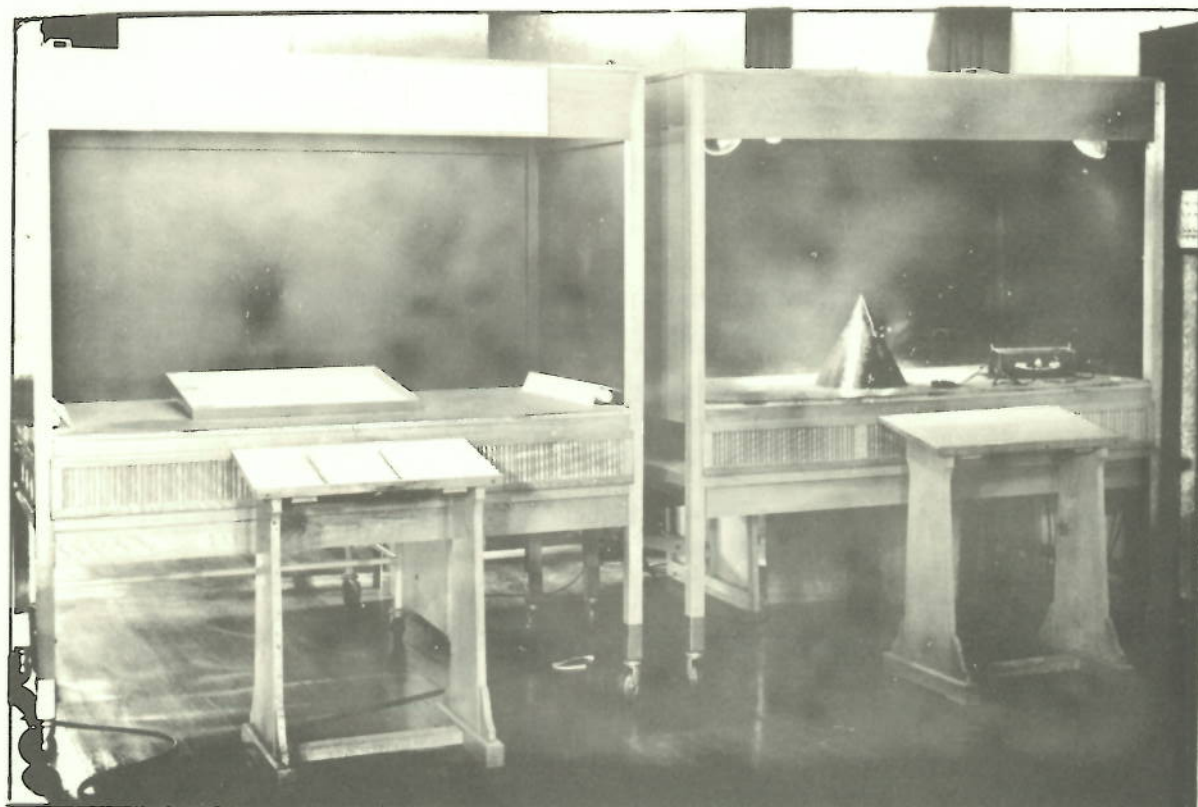
HAND DYNAMOMETER

- Purpose:** To produce and record the various phenomena of muscular fatigue.
- Apparatus:** The force required is adjusted by weights. Knowledge of results, in the form of the number of pulls and extent of pull, can be provided when necessary.
- Experiment:** The subject pulls against different loads and the decrement of performance is measured from the trace on a pen recorder.
- Availability of apparatus:** Designed and constructed at Cranfield.

FUNCTIONAL ANATOMY 4.

CONTROL ERGOGRAPH

- Purpose:** To examine the effect of control movement direction on fatigue rate and available force.
- Apparatus:** The subject's chair can be fixed at any angle in relation to a hand lever. Forces to be pulled against are provided by a pneumatic system.
- Experiment:** Measurement of fatigue rate for different directions of control movement.
- Availability of apparatus:** Designed and constructed at Cranfield.



PHYSIOLOGICAL PSYCHOLOGY 1.

NOISE MEASUREMENT

- Purpose:** To acquaint students with the techniques for noise measurement and to emphasize the necessity for spectral analysis.
- Apparatus:** Tape recorder, noise level meter and frequency analyser.
- Experiment:** Various noises available on tape are set to a standard noise level, using the sound level meter and the intensity distribution with frequency is determined for each.
- Availability of apparatus:** Tape recorder by Simon. Noise level meter and frequency analyser by Dawes Instruments.

PHYSIOLOGICAL PSYCHOLOGY 2.

LIGHT MEASUREMENT

- Purpose:** To provide a variety of light environments in which measurements can be taken.
- Apparatus:** There are three boxes. Box A is fitted with fluorescent tubes of the same colour temperature but different dimensions and power levels. Box B is fitted with 5 ft. 80 watt tubes of different colour temperature. Box C is fitted with a variety of fluorescent tubes and filament lights.
- Experiment:** In a typical exercise the students will plot isophots for different light sources and determine their luminous efficiencies.
- Availability of apparatus:** Designed and constructed at Cranfield, in co-operation with Atlas Lighting.



PHYSIOLOGICAL PSYCHOLOGY 3.

INTERNAL ENVIRONMENT

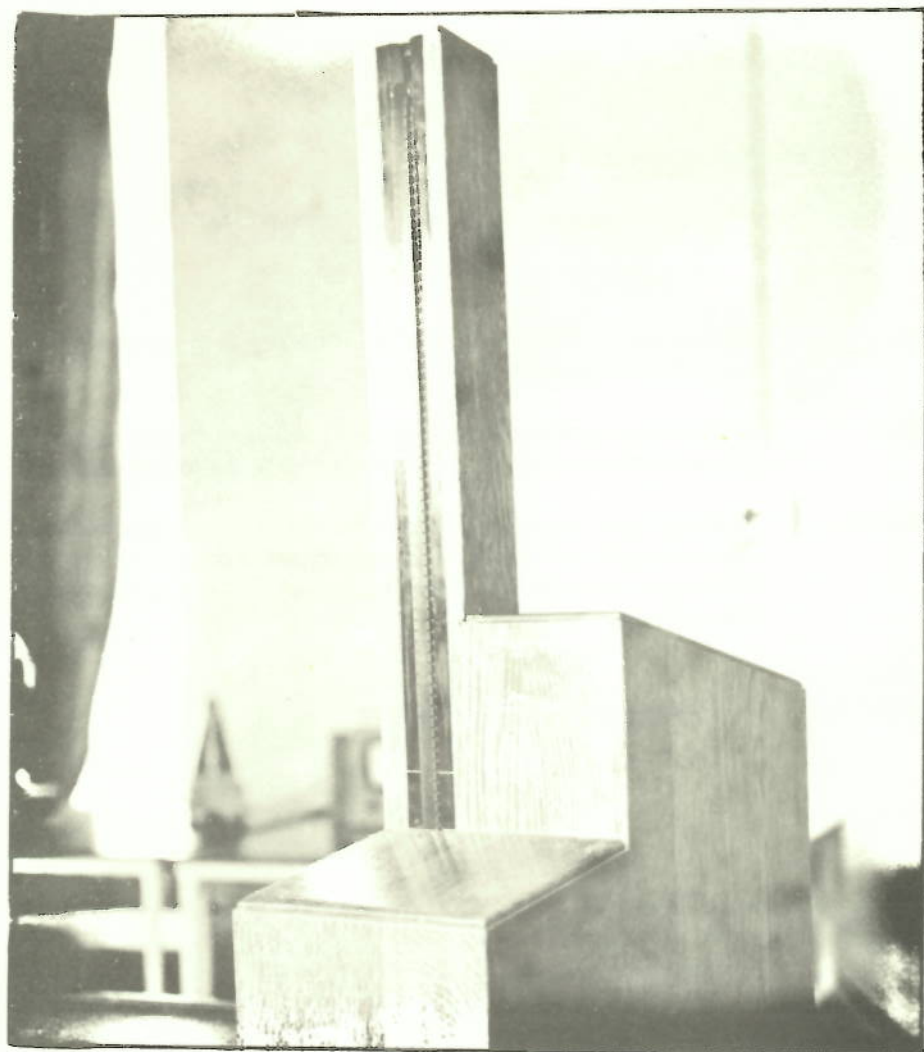
- Purpose: To acquaint students with various measures of metabolic activity which can be recorded.
- Apparatus: Integrating pneumo-tachograph, Muller pulse-rate recorder. Temperature meters. Galvanic skin response meter.
- Experiment: In a typical exercise, this apparatus is connected to a subject who indulges in physical work by walking up and down steps. Correlation between these measures and amounts of physical work is established.
- Availability of apparatus: All commercially available.

PHYSIOLOGICAL PSYCHOLOGY 4.

EXTERNAL ENVIRONMENT

- Purpose: To provide a consistent environment where any phenomenon can be observed under controlled conditions and the effects of environment on performance can be determined.
- Apparatus: A decompression chamber has been modified and fitted with apparatus to control temperature, humidity and air speed.
- Experiment: A great variety of exercises is possible under these conditions.
- Availability of apparatus: Modified at Cranfield from military equipment.





WORK STUDY 1.

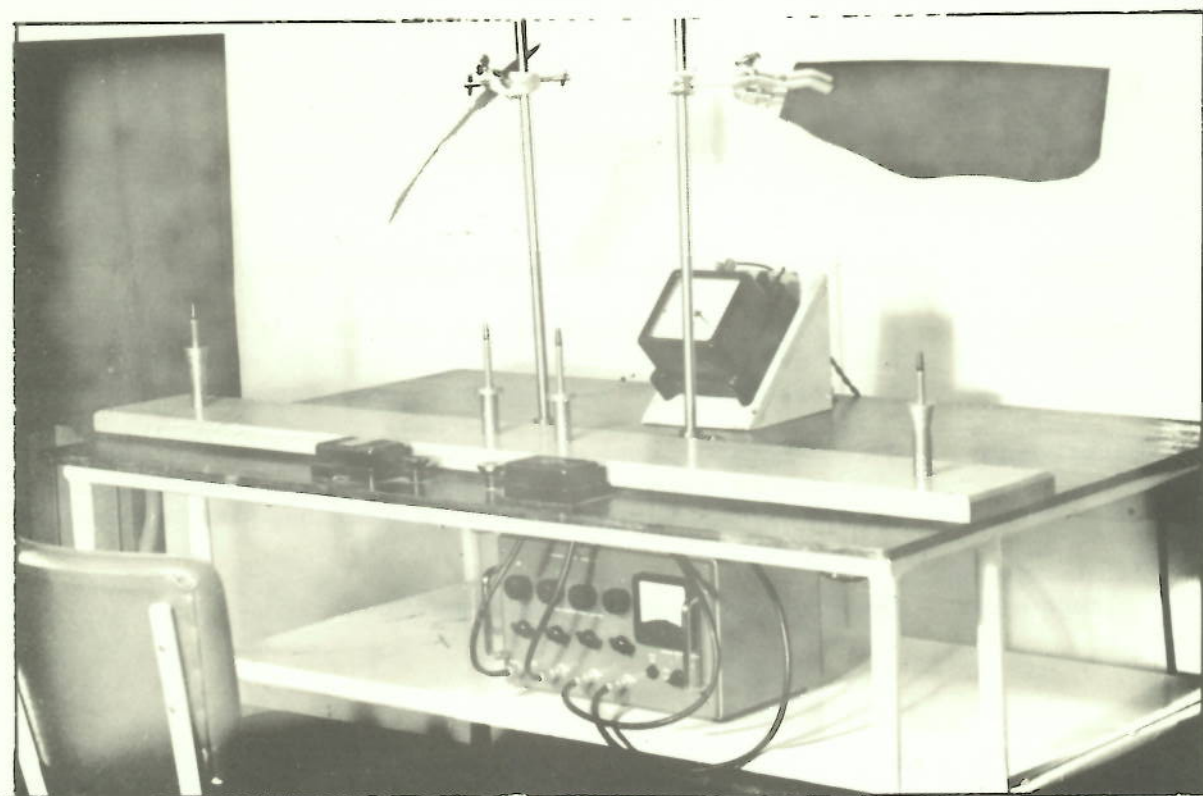
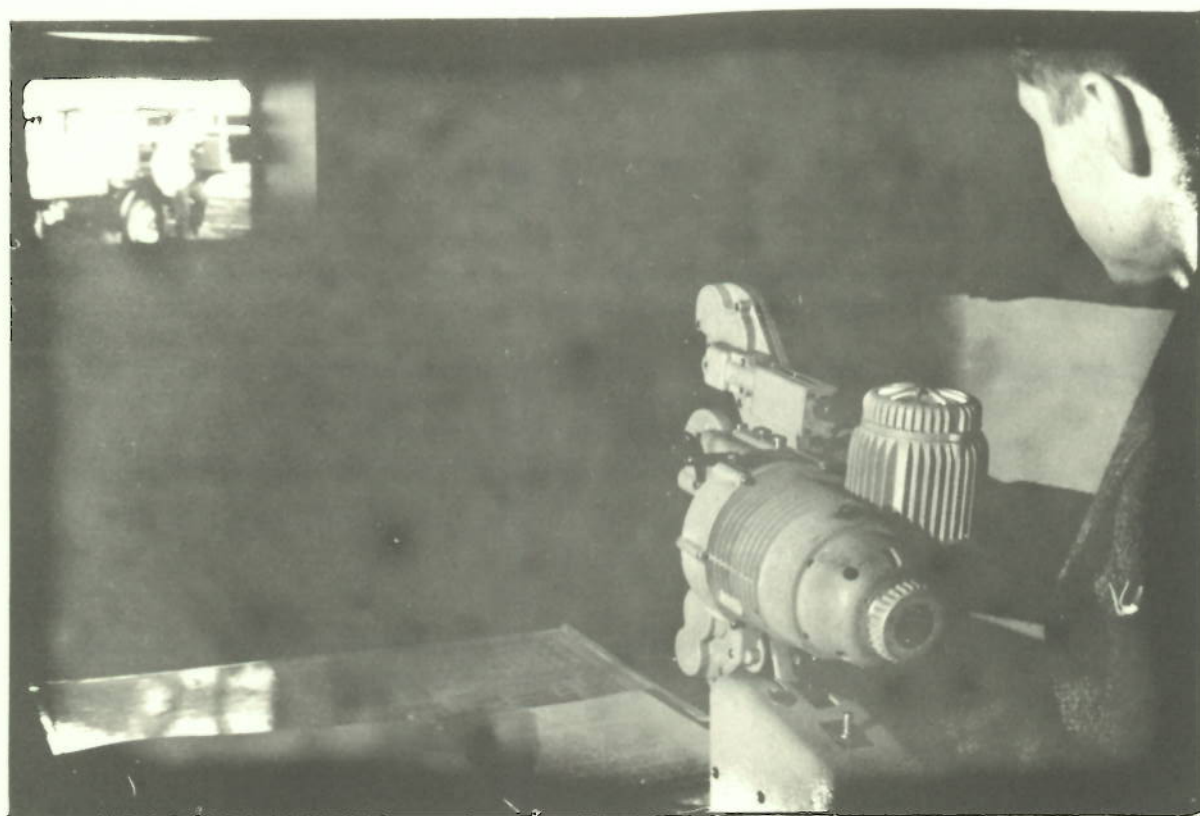
OBSERVED TIMES

- Purpose:** To determine the accuracy of stop-watch timing.
- Apparatus:** A black film loop is marked with white bars at intervals. The times at which successive bars go past a reference point are measured, using ordinary stop-watches.
- Experiment:** This is normally done as a class exercise. The film runs at a constant speed so that standard times are available, and the variation of the observed times about these can be determined.
- Availability of apparatus:** Designed and constructed at Cranfield.

WORK STUDY 2.

REACH TIMES

- Purpose:** To determine the effects of direction and distance of movement on time taken.
- Apparatus:** A brass peg can be fitted at any distance and direction from a similar starting peg. The time at which the subject reaches and leaves each peg is recorded by 'SETAR' via a 'Touch Sensing Unit' which detects contact of the hand with a peg.
- Experiment:** Variation in reach times with distance and direction are plotted for each subject.
- Availability of apparatus:** Designed and constructed at Cranfield, except for 'SETAR' which is available from Rock Electrics.



WORK STUDY 3.

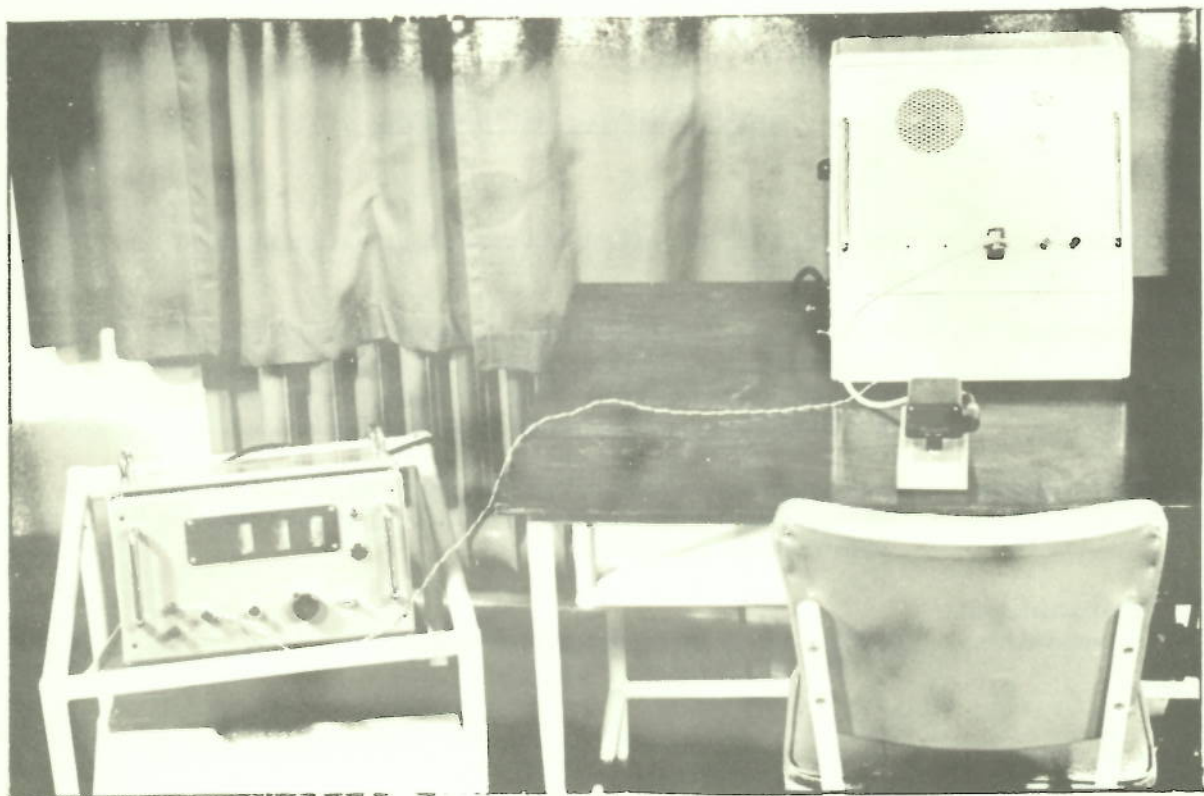
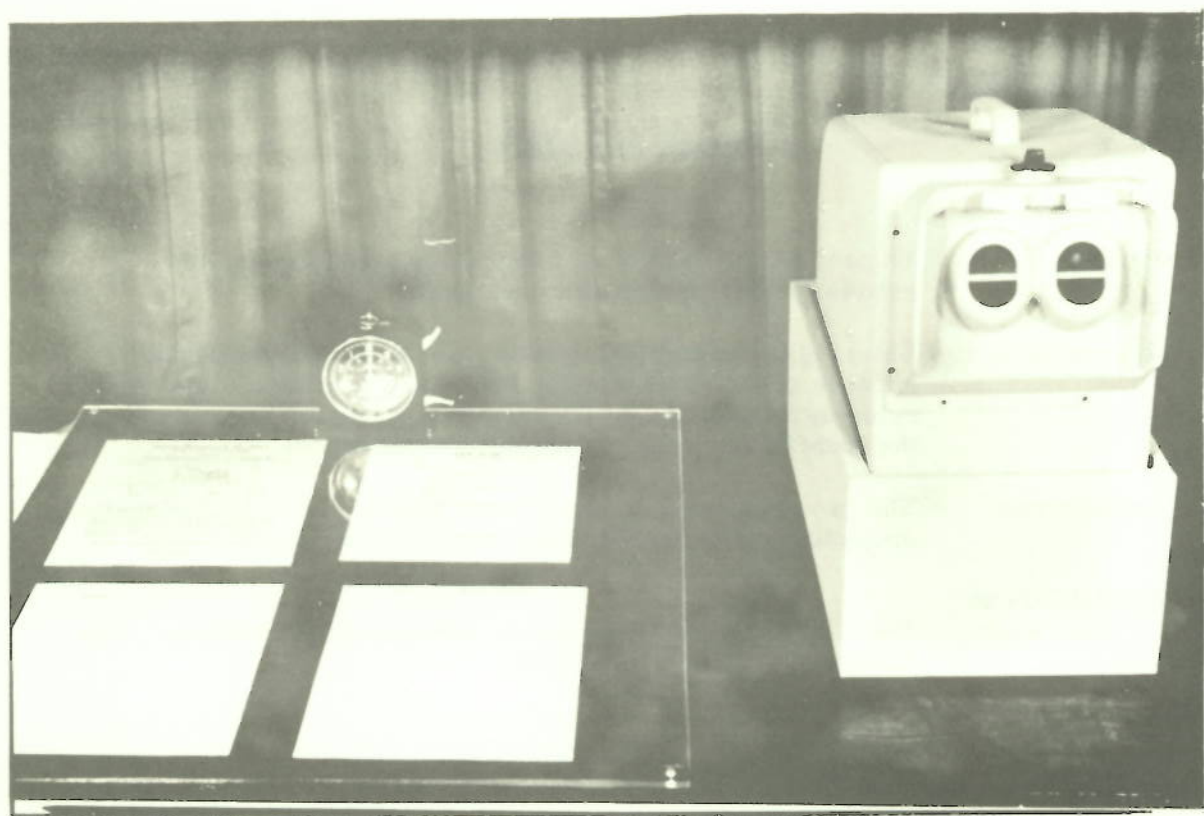
TWO-HANDED MOVEMENTS

- Purpose:** To determine the effect of visual deprivation on hand movements.
- Apparatus:** Washers are moved from two outside vertical pegs to the corresponding inside pegs. This provides a simple analogue of an assembly task. Times can be recorded by a total time counter or by a 'Touch Sense Unit'.
- Experiment:** Learning curves are plotted for one handed and two handed movements, and the effect of removing visual cues on the cycle time is measured.
- Availability of apparatus:** Designed and constructed at Cranfield.

WORK STUDY 4.

DESIGN ANALYSIS

- Purpose:** To provide experience of film analysis and the use of predetermined motion time systems.
- Apparatus:** Entering a commercial vehicle cab is normally difficult because of the front wheel. Films are available of drivers entering cabs designed for the alternatives of going round the front of the wheel or the back of the wheel.
- Experiment:** The two sequences of activity are studied using a film analysis projector and recorded using methods time measurement.
- Availability of apparatus:** The film analysis projector is commercially available. The films were made at Cranfield.



EXPERIMENTAL PSYCHOLOGY 1.

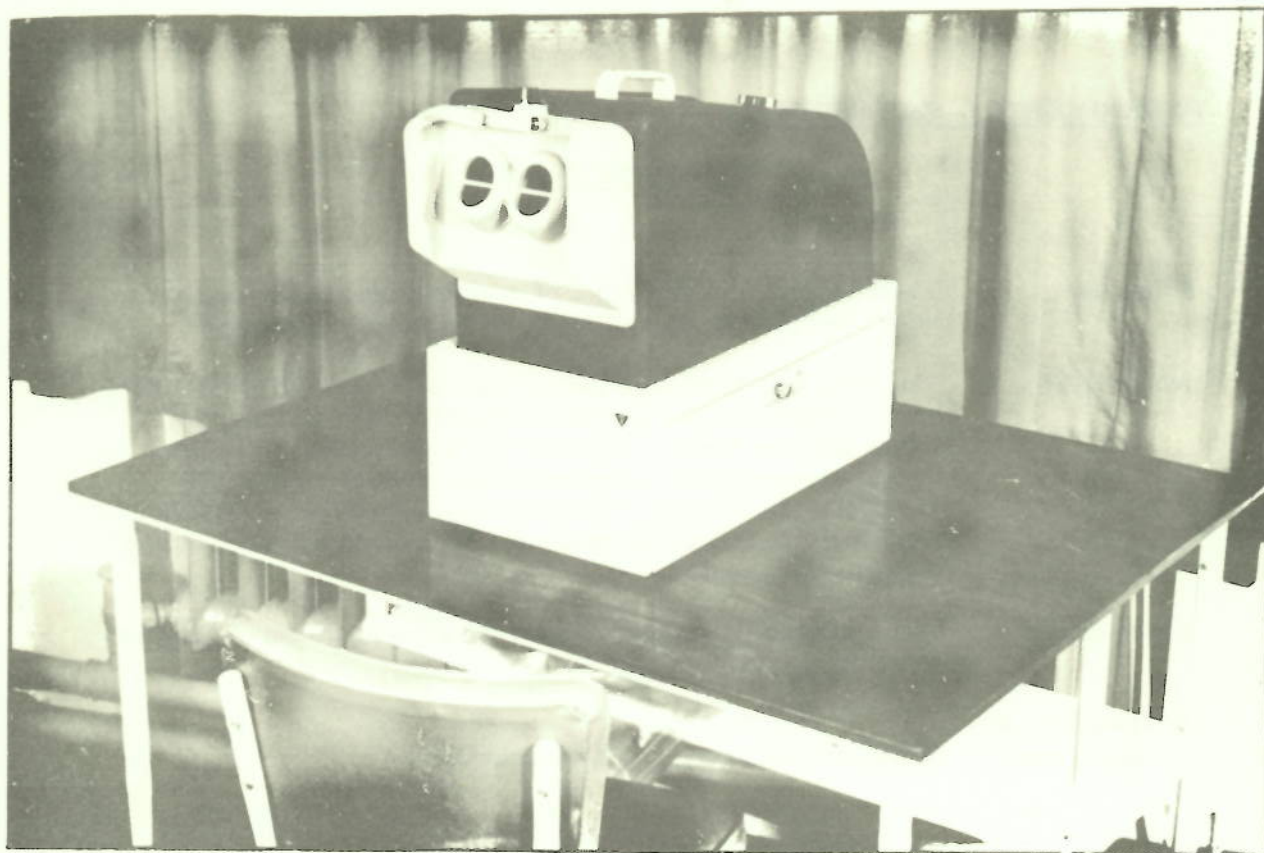
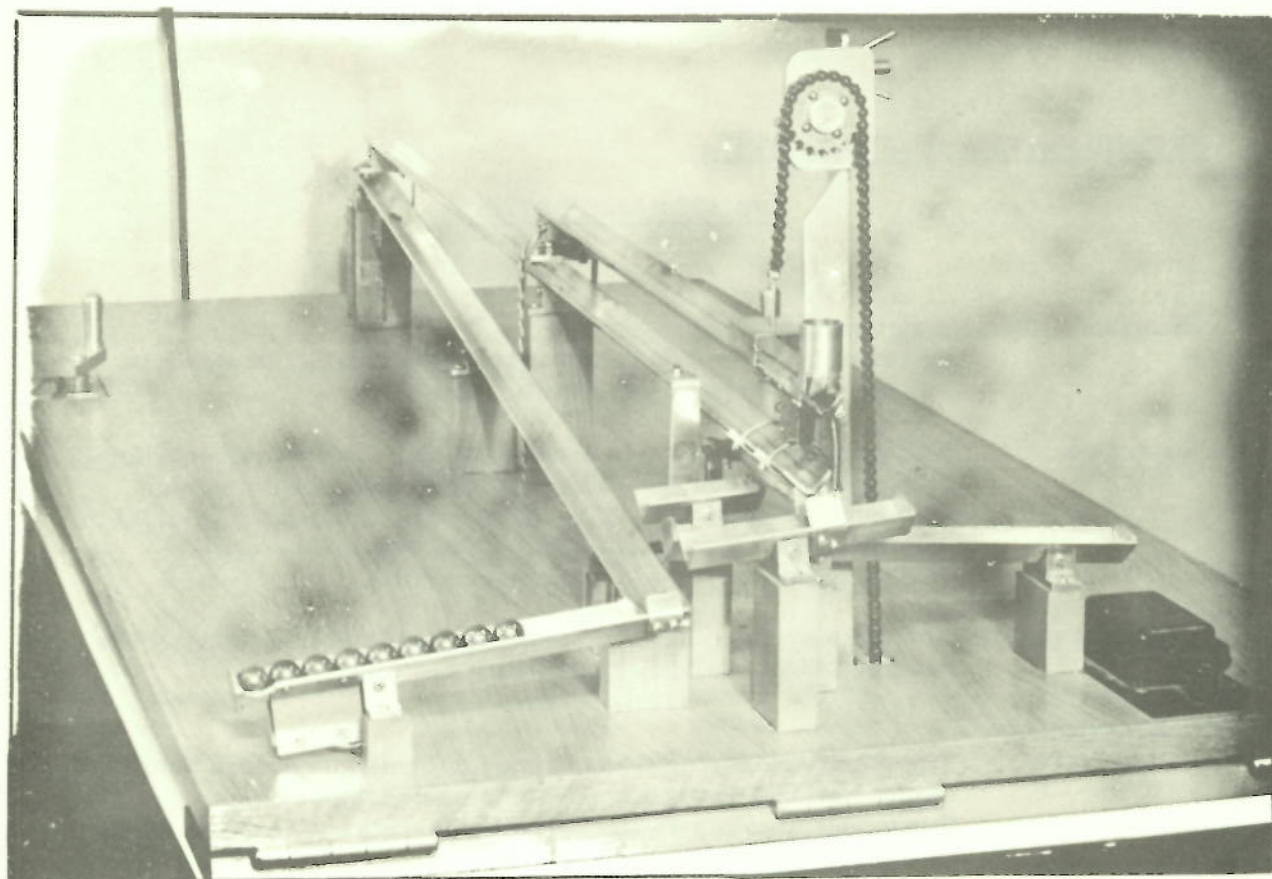
REACTION TIMES

- Purpose:** To determine the variation of reaction time with sensory input, keeping other variables as constant as possible.
- Apparatus:** The response is always the release of a key by the dominant hand. There are six possible stimuli - three tones, two lights and one touch. Expectancy is controlled in that the stimulus appears at a random time interval, within the range 0 to 10 seconds, after the key is pressed. Reaction time is recorded to the nearest millisecond on an electronic digital time counter.
- Experiment:** The distribution times for each sensory mode for a number of subjects are obtained.
- Availability of apparatus:** Designed and constructed at Cranfield.

EXPERIMENTAL PSYCHOLOGY 2.

INDIVIDUAL TESTING

- Purpose:** To acquaint students with:
(a) various paper and pencil tests for a number of abilities.
(b) the various parameters of vision.
- Apparatus:** Standard test forms and an ortho-rater. There are tests for intelligence, speed and accuracy of clerical checking and manipulation of shapes. The ortho-rater measures vertical and horizontal muscle balance, right, left and binocular acuity, depth perception and colour vision.
- Experiment:** The tests are carried out under the standard conditions. The results and the validity of the tests are discussed.
- Availability of apparatus:** The paper tests are standard ones designed by bodies such as the National Institute of Industrial Psychology and Personnel Administration. The ortho-rater is made by U.K. Optical Bausch and Lomb.



EXPERIMENTAL PSYCHOLOGY 3.

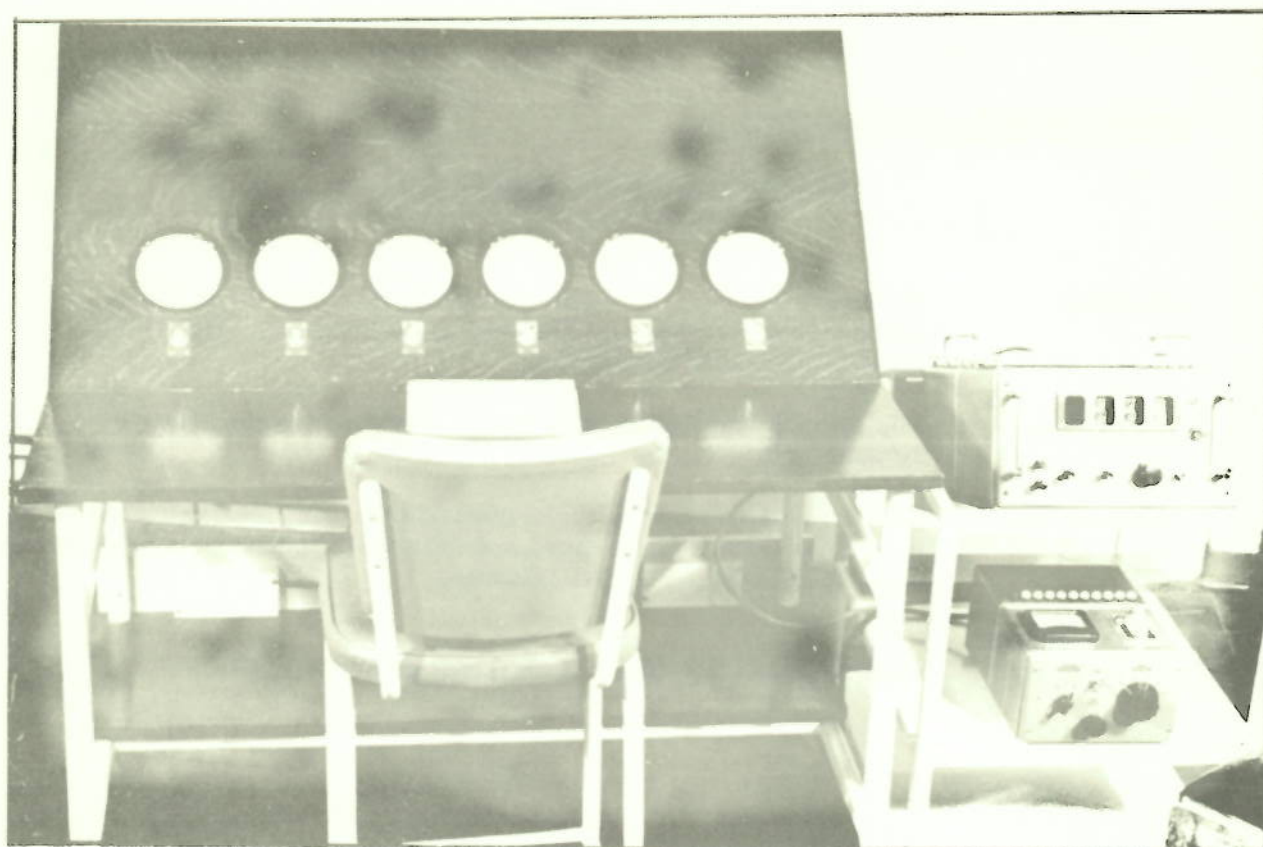
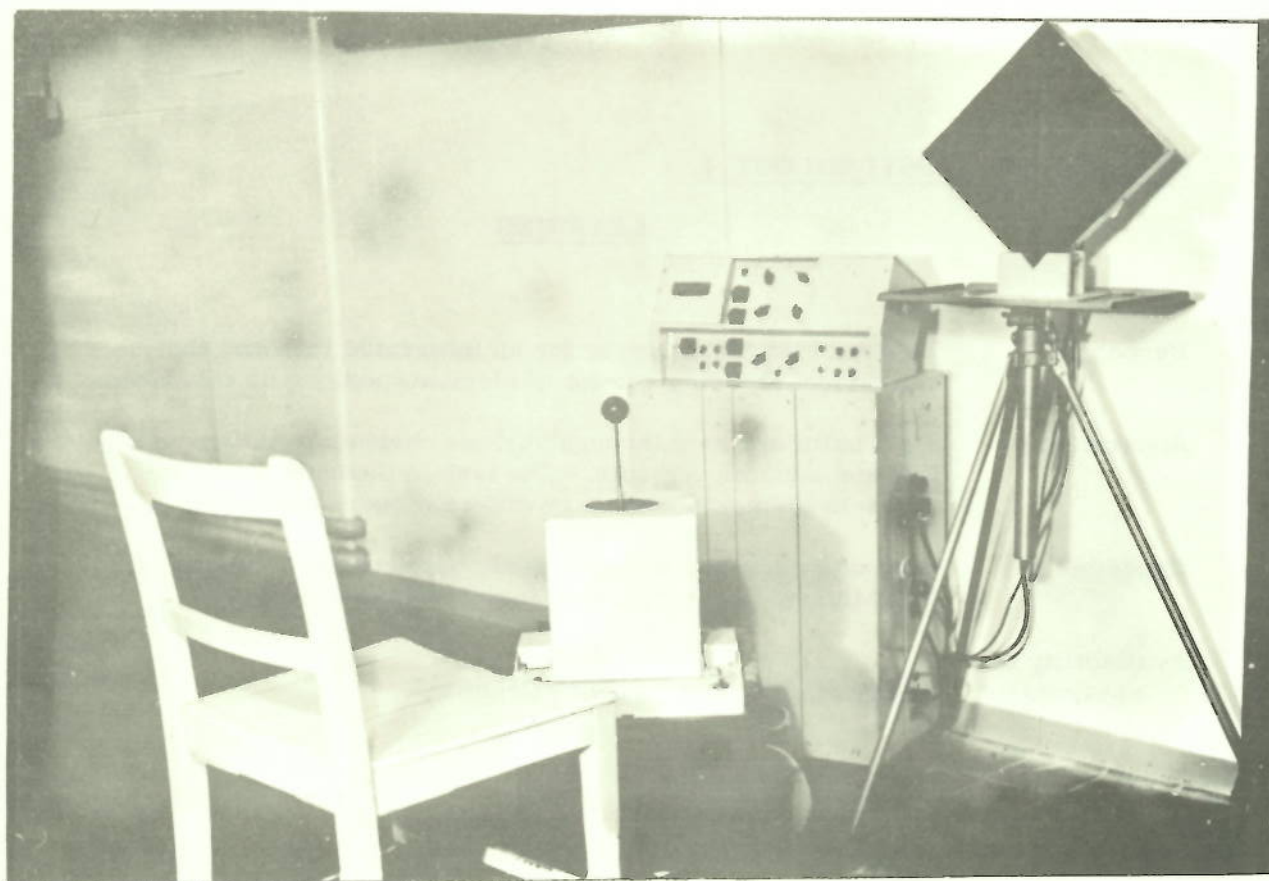
FLICKER FUSION THRESHOLD

- Purpose:** To determine flicker fusion threshold using the three main psycho-physical methods (method of adjustment, method of limits, method of constants).
- Apparatus:** The Bausch and Lomb ortho-rater modified to take a Dawes Strobo-flash.
- Experiment:** Results obtained by the three methods are analysed and plotted in various ways to determine the relative effectiveness of each method for this particular measure.
- Availability of apparatus:** Commercially produced units modified at Cranfield.

EXPERIMENTAL PSYCHOLOGY 4.

LEARNING

- Purpose:** To obtain learning curves for an integrated task and the constituent learning curves of elements making up this task.
- Apparatus:** Steel balls are sent through various channels and directed by foot and hand movements. The task is designed so that different elements have very different perceptual loads.
- Experiment:** Learning curves are interpreted, particularly in terms of the different perceptual load involved in the elements.
- Availability of apparatus:** Designed and constructed at Cranfield.



ENGINEERING PSYCHOLOGY 1.

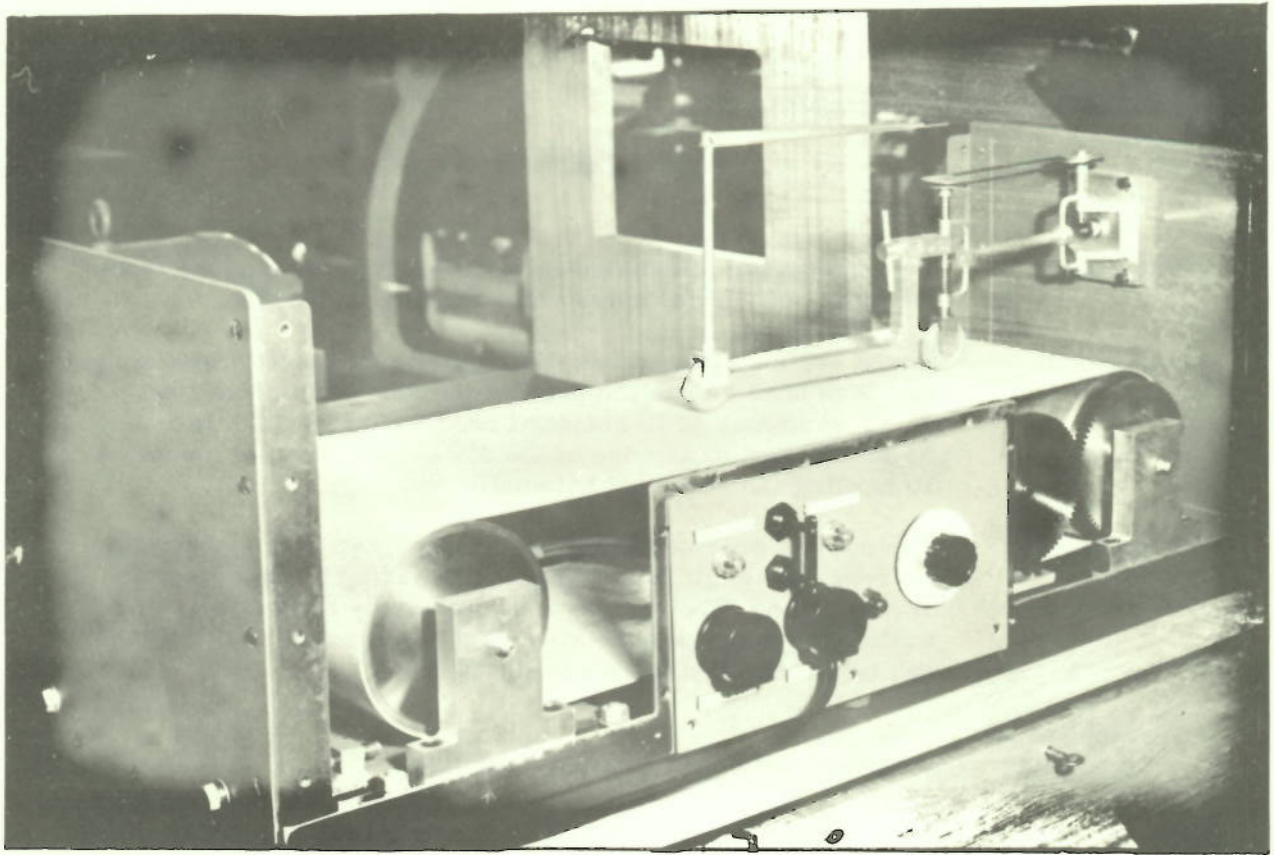
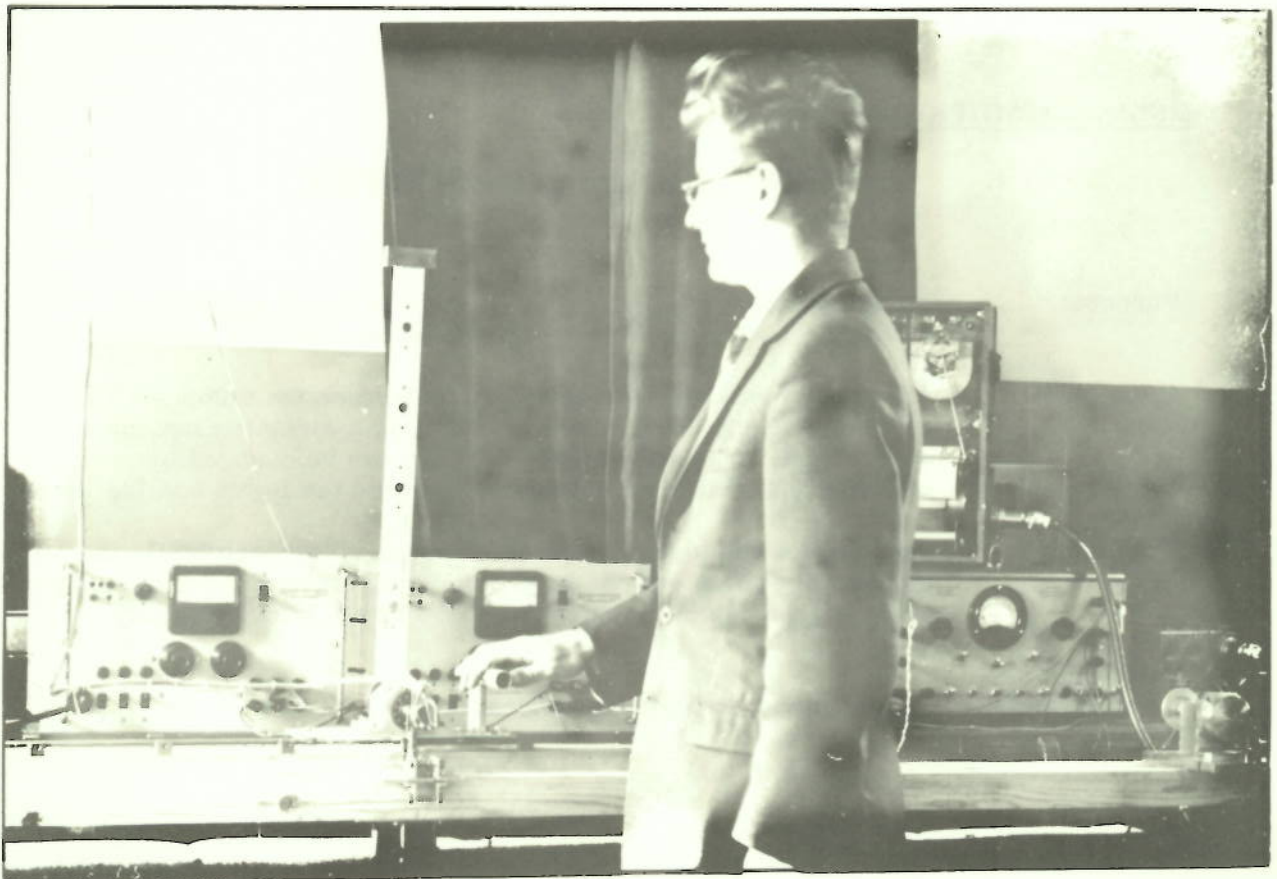
DIAL READING

- Purpose:** To examine the effectiveness of different scale designs from the points of view of speed and accuracy of reading.
- Apparatus:** There are six dials which differ only in that a different method has been used on each to provide the scale from 0 to 100. 60 Programmes of 10 standard readings are available and can be directed on to any one of the dials. The time to complete 10 readings is recorded automatically.
- Experiment:** The subject provides the first reading by pressing a switch. He reads the scale and changes the reading by pressing the switch again. The readings, as spoken by the subject, are written down by the observer. The accuracy of the readings can be checked by reference to tables.
- Availability of apparatus:** Designed and constructed at Cranfield.

ENGINEERING PSYCHOLOGY 2.

DISPLAY-CONTROL RELATIONSHIPS

- Purpose:** To determine the effect of the relative physical orientation of display and control on the speed and accuracy of response.
- Apparatus:** A series of random red lights is provided on the display. The correct response is to move the lever in a direction indicated by the light. The difficulty of the task can be changed by changing the position relationship between the lights and the lever.
- Experiment:** The subject completes a series of trials. For each trial, the number of errors and the total time are recorded automatically. Learning curves are plotted for tasks of differing difficulty.
- Availability of apparatus:** Designed and constructed at Cranfield.



ENGINEERING PSYCHOLOGY 3.

CONTROL DYNAMICS

- Purpose:** To examine the effect of control order on performance.
- Apparatus:** The mechanism connecting the control to the display is such that the subject can be required to track with what is essentially a velocity control, or with an acceleration control.
- Experiment:** The subject's track, under the two conditions, is recorded. The effectiveness of the performance is measured in terms of the root-mean-square error or by using more sophisticated methods such as power density spectra.
- Availability of apparatus:** Designed and constructed at Cranfield.

ENGINEERING PSYCHOLOGY 4.

BALANCING

- Purpose:** To determine the transfer function of the human operator in this particular situation.
- Apparatus:** A small, effectively frictionless trolley is moved to and fro by the subject in order to maintain an unstable rod in a vertical position.
- Experiment:** The movements of the trolley, which the subject makes to maintain balance, are recorded by a pen recorder. Since the dynamics of the physical system are known, it is possible to specify the performance of the operator in the form of a transfer function.
- Availability of apparatus:** Designed and constructed at Cranfield.



A PROJECT IN PROGRESS

Concluding Note

The formal experiments described in this report make up about a third of the total activity in the laboratory. Having completed a selection of these experiments, the students go on to project work where they gain experience in the application of analytical techniques to real problems of system design. For this purpose, the students work in larger groups and study a machine with which they are already familiar from the individual or engineering viewpoint.

If a student intends to specialise in the ergonomics field, he will also be required to carry out individual research reported in the form of a thesis. The laboratory is equipped with a wide range of measuring and recording instruments which can be used in association with the experimental apparatus which the student designs for himself.

Acknowledgements

The rapid development of this laboratory has depended on the encouragement of Professor Loxham and the co-operation of many service sections within the College. Particular mention would be made of Mr. E. C. Sills, Head of the Instrumentation Section, Mr. F. W. Hart Chief Workshops Engineer, Mr. K. P. Harris, Chief Draughtsman, and Mr. T. Gardiner, Senior Ergonomics Laboratory Engineer.