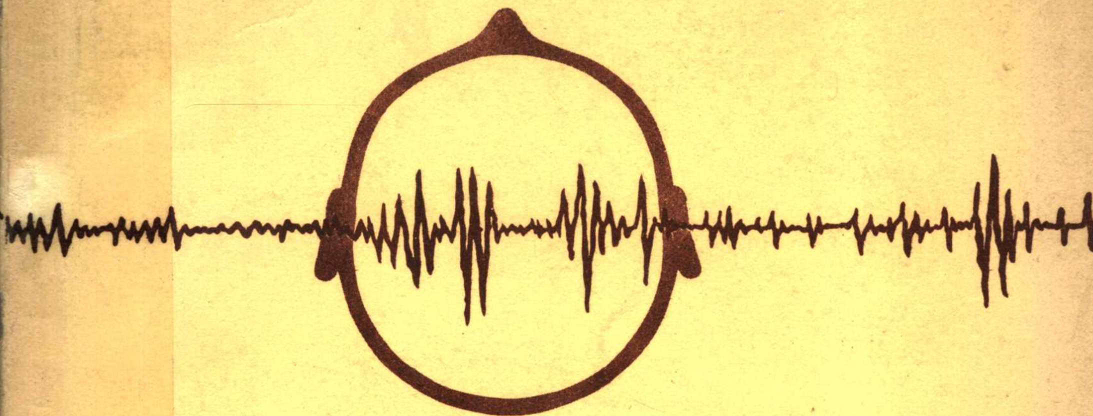

JOHANN KUGLER

Electroencephalography in hospital and general consulting practice An introduction

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ELECTROENCEPHALOGRAPHY IN HOSPITAL AND GENERAL CONSULTING PRACTICE

An Introduction

BY

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With a contribution on
Methods of Activation of the Electroencephalogram by

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Boston, Mass., U.S.A.

and a Preface by

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Paris

ELSEVIER PUBLISHING COMPANY

AMSTERDAM · LONDON · NEW YORK

1964

ORIGINAL TITLE
Elektroencephalographie in Klinik und Praxis
PUBLISHED BY
GEORG THIEME VERLAG, STUTTGART, GERMANY
TRANSLATED BY
Excerpta Medica, Amsterdam

ELSEVIER PUBLISHING COMPANY
335 JAN VAN GALENSTRAAT, P.O. BOX 211, AMSTERDAM

AMERICAN ELSEVIER PUBLISHING COMPANY, INC.
52 VANDERBILT AVENUE, NEW YORK 17, N.Y.

ELSEVIER PUBLISHING COMPANY LIMITED
12 B, RIPPLESIDE COMMERCIAL ESTATE
RIPPLE ROAD, BARKING, ESSEX

LIBRARY OF CONGRESS CATALOG CARD NUMBER 63-22065

WITH 96 ILLUSTRATIONS

PRINTED IN GERMANY

Preface

Electroencephalography in man is a German contrivance: its originator,

Hans BERGER, born on 21 May 1873 in Neuses near Coburg, never left Germany to seek stimulation abroad; his 14 papers dealing with "Das Elektrenkephalogramm des Menschen" were, apart from the second, released in the years 1929—1938 in "Archiv für Psychiatrie und Nervenkrankheiten"; moreover, electroencephalography carries on the concepts of German 19th century metaphysics, philosophy and science.

German scholars exploring psychophysics and psychophysiology, from HERBART and LOTZE to FECHNER, from WUNDT to ZIEHEN and LEHMANN, studied the relations between brain and thinking, between physical and mental energy, and between sensation and introspection*. Endeavouring to solve the problem of the body–mind relationship — a task perhaps too great even with the scientific means now available — Hans BERGER examined cerebral circulation and temperature, the bodily expression of mental conditions, to turn, after many frustrations, to cerebral electricity recorded superficially from the skull.

Was Hans BERGER an original thinker? Professional philosophers or prominent neuropsychiatrists of his time would certainly not have said so. Could he then, at least be classed as an electrophysiologist? His colleague BIEDERMANN would have been the last to regard him as a successor to E. DU BOIS REYMOND. What was BERGER then? The man who first applied electroencephalography to the human was a witty, hard working, methodical man, indifferent to the glamour and bustle of the world

* FISCHGOLD, H.: Hans BERGER et son temps. In "Actualités neurophysiologiques", 4. Serie, Masson et Cie., Paris (1962).

FISCHGOLD, H.: D'Angelo Mosso à Hans BERGER. Symposium Internationale di storia della Nevrologia, Varenna, 30. 8.—1. 9. 1961, in press.

FISCHGOLD, H.: Les sources de l'EEG de H. BERGER. Internat. Symposium on "Die Entwicklung der kontinentalen Physiologie im 18. und 19. Jahrhundert mit besonderer Berücksichtigung der Neurophysiologie", Münster/Westf., 18.—20. 9. 1962, in press.

around him; a scientist who, on the western front in 1917, was reading SPINOZA and AUGUSTINUS; while his mind was occupied with the problem of mental energy, its origin and its changing forms, he preserved a purity of mind and a feeling for poetry, flowers and stars. He devoted himself to collecting stones and EEG records with equal eagerness. In 1921, he wrote: "One should love what one hopes for, and thus create only what one loves." What perception! It would be good if our young German friends looked again into BERGER's 14 papers, which are still fascinatingly topical*.

In spite of the efforts of this unusual man, clinical electroencephalography had, as it were, to be "brought home" to Germany, via the United States, Canada, Great Britain and the rest of continental Europe; it came back streamlined and electronic, but stripped of its spiritual background and distinguished attributes.

Thus, since 1950, electroencephalography has become a method of clinical examination accessible to all skilled technicians. It is a modest tool of the science of neurology, but has been granted no admittance to the realm of psychiatry. It has provided a strong stimulus to all fields of neurophysiology and, besides, to neurology, neurosurgery, paediatry, forensic medicine, resuscitation techniques, cardiac surgery, psychology, and the list is as yet far from complete.

Almost all these aspects are discussed by KÜGLER in the book before us. Thanks to his ability to read the German, French and English authors in the original, he gives a condensed picture of the results presented in the vast literature on clinical electroencephalography.

Johann KUGLER was born in Vienna in 1923, a few months before BERGER's discovery of the EEG; he studied medicine in Munich and Vienna, and obtained his degree in Vienna at the beginning of 1949, the year in which the first number of the EEG Journal appeared, and the International Federation of Societies for Electroencephalography and Clinical Neurophysiology was founded. After studying general medicine, surgery, anthropology and psychology — the latter under ROHRACHER, the pioneer of EEG in Austria — he chose to specialize in electroencephalography. In 1962, he was appointed lecturer at the Medical Faculty of the University of Munich.

In this book, KUGLER never loses sight of the problems of physician and patient; one has the impression that he, as an EEG specialist, works hand in hand with other technicians engaged in exploring the central nervous system. In this manner, through fruitful consultation with fellow workers approaching the problems from different angles, the danger of an autistic treatment is avoided. At the Hôpital de la Pitié in Paris — where KUGLER followed the organisation of our work with interest—EEG is regarded as one of several *biophysical examination methods of the brain,* apart from which we have:

neuroradiology, with increasingly specific methods,

gamma encephalography, a twin sister complementary to, but distinct from, electroencephalography,

* These articles have not been re-edited; still, they can be found in the back numbers of the "Archiv", and can be reproduced by photographic techniques.

rheography of cerebral pulsations, *echography* of the median brain structures by supersonic vibration, *auscultation* of the cerebral blood circulation by infrasonic waves.

Although the last three methods still present technical difficulties, they will be improved before long.

Bearing the reader in mind, KUGLER refrains from using the jargon of the initiated; he avoids fashionable hypotheses and the phraseology reserved for neurophysiology. His main concern is the physician's course of action after consulting the patient's EEG record. With this in mind, he defines the problems pertinent to each chapter, clearly outlining the contribution that can be expected from the EEG, understating rather that overstating its role.

Still, beyond the confines of clinical electroencephalography as discussed by KUGLER, the method is developing further. The new discipline will probably adopt BERGER's spontaneous electrical activity as an index of the fluctuation and extinction of waking conciousness, preserving the precepts concerning the electro-clinical symptoms, which form the essential part of this book. We anticipate that it will expand to cover even the study of stimulus responses underlying the work of R. CATON and FLEISCHL VON MARXOW, which led to the first graphically reproducible results in the animal experiments of KORNMÜLLER, FISCHER and BREMER. To evaluate stimulus responses registered on the human skull, they are stepped up by means of electronic instruments, which at the same time calculate their mean values and yield superposed records of the spontaneous activity (DAWSON, ROSENBLITH, Mary BRAZIER*). The various parameters (amplitude, frequency, phase), too complex to be evaluated by our time–voltage records, can also be classified, quantified and expressed with the aid of special computors.

We can follow the disintegration of the macro-complex waves in the EEG records, as observed by R. JUNG and others in quick succession, into single records**; CASPERS*** described the fleeting forms of the "Berger-waves" against the background of voltage fluctuations due to cell polarization. Thus, *surface-electroencephalography* — registered from the entire cortical hemisphere — gives merely a small part of the immense amount of information available from the brain.

Using needle electrodes inserted stereotactically into the brain substance, the classical EEG becomes *three-dimensional: intracranial.* Also, think of the technical advantage of having transistor amplifiers of ever smaller size in place of

* See "Problèmes de base en électroencéphalographie", Ed. FISCHGOLD, H., DREYFUS-BRISAC, C. and PRIVOT, Ph., Masson et Cie., Paris (1963).

** CREUTZFELDT, O.: Activité neuronique du Système Nerveux Central. In "Problèmes de base en électroencéphalographie", Ed. FISCHGOLD, H., DREYFUS-BRISAC, C., PRIVOT, Ph., Masson et Cie., Paris (1963).

*** CASPERS, H.: Die Entstehungsmechanismen des EEG. In "Klinische Elektroencephalographie", Ed. R. JANZEN, Springer Verlag, Berlin-Göttingen-Heidelberg (1961).

the bulky EDELMANN galvanometer used by BERGER. Another step forward is that EEG records can now be *telemetrically* transmitted in the same manner as radio and television waves, and thus EEG has entered the cosmos*.

While the followers of BERGER — with KUGLER among the leaders of the young set of German electroencephalographers — exploit every aspect of classical EEG, Richard JUNG reverts to a 19th century theory: in the field of the optic system he coordinates psychophysiological and neurophysiological experiments. He compares the microphysiology of the optical cortex of the cat with the introspective physiology as devised by HELMHOLTZ and HERING**. This rapprochement of subjective psychological experience and objective physiological findings evokes FECHNER's psychophysical parallelism that had also preoccupied BERGER, in spite of the difficulties. A similar rapprochement is simultaneously studied by ROSENBLITH and his colleagues in Boston, by JOUVET and his team in Lyon, in the Hôpital Henri Roussel and the Hôpital de la Pitié in Paris.

Let us return to the author and his book. I first met KUGLER more than ten years ago, at a congress of neurosurgeons in Bad Ischl. I saw him in his modest laboratory in the local hospital for neurosurgery, evaluating his records — after an initial training in electroencephalography at the Vienna clinic for nervous diseases, by self-tought methods — as we all did at the time. Later, he joined the staff of the fine clinic at the Nussbaumstrasse in Munich, directed by the eminent humanist Professor Kurt KOLLE, once a disciple of BERGER. There, KUGLER acquired the strict judicious standards that mark Professor DECKER's neuroradiologic diagnoses; the discipline of morphology also left its imprint on his EEG work.

KUGLER studied in Austria, Germany and France. We meet frequently, and I should like to take advantage of this opportunity of thanking him for the fine translations he does for me whenever I have to address German audiences: as an interpreter he is quick to grasp the idea behind the words.

KUGLER is a keen observer and listener. This book, the result of long and hard work, advocates no theoretic views, nor does it draw bold conclusions. The family of EEG-workers scattered all over the world, who have been following the road mapped out more than a quarter of a century ago by BERGER, has bold as well as cautious members. The energy of the former is a powerful drive, while the caution of the latter checks the hazards involved. KUGLER is one of the cautious, the doctor in him restrains the temptation for experimentation.

Electroencephalography in Hospital and General Clinical Practice matured slowly. Throughout, the author carefully weighs whether the queries of neurologists or other clinicians should be answered by "yes", "either-or", or simply "no". This

* The EEG in relation to space-travel. Symposium, Los Angeles. EEG Clin. Neurophysiol. 15 (1963), 164—166.

** Neurophysiologie und Psychophysik des visuellen Systems. Symposium, Freiburg/Br., 28. 8.—3. 9. 1960, Ed. R. JUNG and H. KORNHUBER, Springer Verlag, Berlin-Göttingen-Heidelberg (1961).

consideration prevails on every page, particularly in the sections dealing with Problem formulations: the reader is shown what to take as certain, probable, or fallacious. The conclusions presented are not those of particular teams or schools, but a critical selection derived from actual experience.

The manual is presented simultaneously in German and English. The substantial portion assigned by the author to French electroencephalography enhances the European character of the book, and permits me to consider Dr. KUGLER as one of us.

H. FISCHGOLD
Professor of the Medical University
Paris

Paris, March 1963

Contents

Ἐν τῷ ἐγκεφάλῳ
τὸ ἡγεμονικόν

Alkmaion, the Pythagorean

I. Principles of electroencephalography

History

The Jena psychiatrist Hans BERGER, in the face of all critical objections to his discovery, could hardly have believed that specialists in his own country would later be so well disposed towards him as to consider nominating him for the award of the Nobel prize. He did not live to see the successful introduction of electroencephalography as an aid in neurological diagnosis throughout the world (30, 30a, 38, 128, 184, 319).

It is true that, before his time, there had been investigators who – on the basis of GALVANI's discovery (1791) – had suspected that the muscle-controlling central nervous system was capable of initiating electrical impulses. CATON, in London, succeeded in furnishing evidence of this in animals in 1875, and his findings were confirmed by FLEISCHL von MARXOW (1883) in Vienna and by BECK (1890) in Cracow. In view of the technique used at that time, it is not surprising that the results obtained were variable. Hence the authenticity of electrical impulses as manifestations of phenomena accompanying ganglion cell function remained in doubt for a long time. Thus according to TSCHIRIEV (1904), the electromotor effects were dependent upon the changeable blood volume in the cerebral cortical vessels. It was only in 1912 that this view was definitely refuted by KAUFMANN. In his description of electrical phenomena in the cortex of dogs (1913–1925), PRAWDICZ-NEMINSKI came very close to our present day views. He distinguished between seven types of wave in the "electrocerebrogram", but was unable to draw any conclusions applicable to clinical medicine in human beings.

It was BERGER (a grandson of Friedrich RÜCKERT [cf. 201, 333]) who, in 1924, succeeded in obtaining the first electroencephalographic tracings from the intact human scalp. At first he used two silver needles as leads and made his observations on a wire galvanometer; he discovered, in the occipital regions, regular fluctuations in potential which amounted to only one-twentieth of the ECG voltage, and which he called alpha waves (α waves, see*). He postponed publi-

* In the following text, the symbol α will be used for both alpha and alpha wave(s). Specialists refer to alpha activity, alpha spindles etc., instead of alpha wave activity (α activity), alpha wave spindles (α spindles). The same holds true for the other wave bands and their Greek symbols.

cation of his results until 1929 and persisted in his investigations until by 1939, he had anticipated almost all our fundamental observations, thus becoming the founder of clinical electroencephalography. His first publications were rejected by physiologists and neurologists. In 1910 electrocardiography had demonstrated that myocardial activity was accompanied by electrical phenomena which were in definite proportion of the amount of energy expended. Inactive tissue produced no electrical discharges. The postulate that the "Berger rhythm" appeared only at rest and disappeared when the eyes were opened, seemed to be in direct contradiction to the experience so far gained. However, since the investigations conducted by the English physiologist ADRIAN (5) in 1934 in well-screened Faraday cages under incontestable experimental conditions, there is no longer any doubt as to the basic rhythmic activity of the resting human brain.

Initially, few investigators in Germany made use of BERGER's ideas. KORNMÜLLER (203, 205) 1932 observed differences in electrical activity between various cerebral cortical fields by direct recording from the cortex and later from intact skulls (204) of animals (particularly rabbits and cats). He was also the first to describe "convulsive discharges" in epileptics. In 1934, ROHRACHER tested the method for its usefulness in psychological problems (316), and developed an α wave theory (318). TÖNNIES (358a) as well as FOERSTER and ALTENBURGER (100) reported in 1934 and 1935 the first direct records from a human cerebral cortex during a cranial operation.

After ADRIAN's publication, in 1934, electroencephalography was taken up with greater enthusiasm in Anglo-American countries than in BERGER's native country. JASPER (176, 178) has since recorded in numerous "open head" surgical cases. GIBBS, DAVIS and LENNOX (129) – extending KORNMÜLLER's general theory of "Krampfstromentladung" — correlateda regular spike-and-wave pattern occurring at 3 c/sec, with petit mal. In 1936 GREY WALTER introduced the technique of tumour localization with the EEG (373).

At the first International Congress of Psychologists in Paris (1937), BERGER had the satisfaction of seeing his work recognized. World War II broke out and, for years, paralysed the technical development of electroencephalography in Europe. In 1941 BERGER committed suicide. During the war, attempts were made to make practical use of the EEG in testing the fitness of airmen and in cases of cranial injury (336). In Germany, the "neurograph" developed by TÖNNIES (357) in 1932 remained for a long time the model for the first EEG appliances. American industry, however, suffered less severe damage during the war and a number of firms began mass production of a standard type of EEG apparatus.

In the past, pre- and main amplifiers, which together form a channel, were built separately. Consequently even 3- or 4-channel apparatus incorporating a loop oscillograph, were both heavy and immobile. The progress made in amplifier techniques has led to the construction of modern designs of easily arranged, space and weight-saving apparatus. Portable apparatus containing 8 or more channels can now be brought from the laboratory to the operating theatre or to the bedside. Electroencephalography has since shown rapid development, although it has, of course, failed to fulfil the expectations of psychologists and psychiatrists.

Technical notes

Methods of recording

Prior to 1913, bioelectrical phenomena had to be studied with the aid of a capillary electrometer; today it is almost impossible to understand how fundamental findings could have been achieved with such instruments even by the end of the 19th centrury. The introduction of the EINTHOVEN galvanometer was a decisive step forward, to which electrocardiography owes its first applications. In electroencephalography, it was only the development of amplifier valves and cathode-ray oscillgraphs that enabled recording of processes over longer periods of time. Initially, fluctuations in potential could only be recorded with the aid of light-sensitive films. This indirect method of recording needed much time spent on developing the films, and direct observation of activity was impossible. Recordings of adequate length, moreover, were expensive. Attempts at replacing photographic film by chemically sensitive paper strip offered no great advantage. They have become almost insignificant in actual practice since the introduction of direct recording, which is generally used now in commercial EEG and ECG apparatus. Two types of design can be distinguished.

1. Ink-writing, in which fine metal tubes write on paper or in which moving jets spray ink on a paper strip rolling around a cylindrical drum.

2. Dry-writing, in which hot metal filaments slide over wax-covered paper or in which moving metal springs press carbon paper against paper drawn over a knife-edge, thus imprinting traces of the carbon paper on the moving paper.

Both systems have their own particular advantages. That of the ink-writer lies in the sharp contrast of the tracings, while the superiority of the dry-writing method with carbon paper is seen in the Cartesian ordinate system (i. e. the spring which pivots on a vertical axis does not draw small arcs when deflected upwards or downwards, but imprints a linear trace through the counterpressure against the knife-edge; the time coincidence is thus maintained).

Amplifiers

Not everybody can detect and repair faults in the apparatus. Any intelligent technician, however, like any trained physician working in an EEG laboratory, should be able to change a faulty tube. One must presuppose, however, that they possess a knowledge of the component parts of an EEG and their wiring. The principles underlying the design of an EEG amplifier correspond with that of a radio amplifier; its input amplifier chiefly amplifies voltage, and its main and output-amplifiers amplify both voltage and current. Nearly always, the amplifier operates by a special push-pull system (341) which suppresses external interference. Two tubes form one amplifier stage. The majority of commercial EEG amplifiers combine four such tube stages in a cascade circuit. Since stabilizers have been developed in the circuit which neutralize fluctuations in the mains supply system, battery amplifiers have been abandoned in Europe; as a rule, all-mains amplifiers, directly connected with the alternating current supply are used.

An amplifier, with all its associated stabilizers, valves, condensers, and the recording system connected with its outlet, form a channel which can be used in recording potential changes between two electrodes. A single record is no longer considered satisfactory, even during simple anaesthesia control. Four channels are regarded as the minimum for encephalography. In laboratories carrying out regular and constant EEG investigations, 8 channels are appropriate. Twelve, sixteen or more channels simplify the interpretation of the recordings. In routine recording, they offer the possibility of simultaneous assessment of several electrodes; they improve the localization of foci and permit polygraphic investigations, i. e., simultaneous recording of the EEG, ECG, respiration and other electrical and mechanical phenomena. Paroxysms occurring once or twice during a record can be localized only when they are observed simultaneously at as many sites of recording as possible. However, an increasing number of channels cannot be expected to be paralleled by an increase in positive EEG findings or a saving of time. One's ability of interpreting curves visually has certain limits; 8-channel tracings can be read easily. Many interpreters find it difficult, however, to read 12 channels rapidly and completely. To read records form 16 or 30 channels efficiently requires special training.

Amplification must be adjustable in every channel. Generally, the adjustment is made so that 50 μV correspond to a deflection of 5—7 mm. Every channel must have filters for both low and high frequencies, to limit the transmitted frequency range from above or from below. Interference filters (muscle filters) suppress the fast activity — a suppression that may be necessary in examining tense patients. Time constant switches eliminate slow fluctuations in the base lines, which distort the records in restless or sweating patients. An attempt must be made never to use filters below 70 c/sec and a time constant shorter than 0.3 sec.

The time constant of an EEG amplifier is the time taken for a direct current pulse produced, e. g., by depressing the push button switch to fall to about one third of its initial value. The time constant is related to the low-frequency response ($f_{gr} = \frac{1}{2\pi x t}$ in which f_{gr} is the low frequency response and t is the time constant). The customary constants yield the following low-frequency responses:

$$t = 1.0 \text{ sec}; \; f_{gr} = 0.16 \text{ c/sec}$$
$$t = 0.3 \text{ sec}; \; f_{gr} = 0.5 \text{ c/sec}$$
$$t = 0.1 \text{ sec}; \; f_{gr} = 1.6 \text{ c/sec}$$
$$t = 0.03 \text{ sec}; \; f_{gr} = 5.0 \text{ c/sec}$$

The waves below these values show increasing distortion. The slower they are, the smaller they are in the record. At the "lower frequency response" the reduction is 29 %; at higher frequencies it is practically insignificant.

The reduction of fast waves in the upper frequency response region shows similar behaviour. At filter value 30, for example, the upper frequency is adjusted

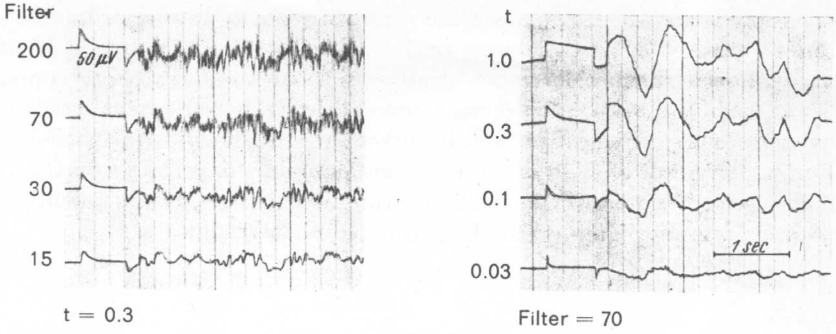

Fig. 1. Left: Frequency filters with various values. The higher the filter value, the larger the fast waves. (Time constant t = 0.3.) Right: Various time constants (t). The longer the time constant, the larger the slow waves. (Filter 70.)

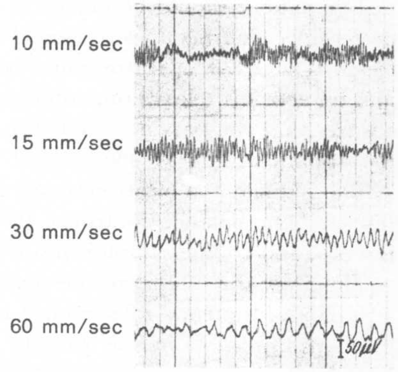

Fig. 2. α rhythm at different paper speeds. Time (1 sec) marked on upper edge of each of the 4 strips. (Effect of eye closing at 10 mm/sec.)

at 30/sec. Slower waves are undistorted but those above this limit are greatly reduced.

The electrodes are connected to the input of the machine by means of thin, flexible leads. The inputs are clearly arranged on a small panel or switchbox, from which a common cable goes to the switch-panel of the apparatus. The switch-panel has two lead-selection switches for each channel, by which either of the two inputs of a channel can be connected with any selected electrode. Many apparatus have master selector switches; they save the trouble of adjusting the separate lead-selector switches. Most apparatus have switch-panels with main attenuators or master switches which in one movement can simultaneously reduce the amplification in all channels by the same amount. This is an advantage in recording high-voltage paroxysmal processes.

Paper speed

In most German laboratories, EEGs are recorded at a paper speed of 30 mm/sec. At this speed the α waves are clearly visible, and their frequency can be readily determined, and the faster waves are recorded without distortion. In other laboratories (nearly all French laboratories) a paper speed of 15 mm/sec is used; this makes slower fluctuations more clearly visible and reduces paper consumption. Counting of the α waves, however, is more difficult. Lower papers speeds (10 mm/sec and slower) or so-called "smear curves" are suitable only for special purposes. Fast paper speeds of 6, 10 or 20 cm/sec are desirable for certain special recordings, higher velocities are difficult to obtain with direct writers. Rapid potential changes (e. g. in electromyography) are best recorded photographically.

Room and screening

The patient should be placed in a room, not too brightly lit, not too noisy and preferably acoustically screened. The apparatus should be in a directly adjoining room. The EEG operator must be able to view the patient through a window and observe his relaxation, consciousness, incipient attacks, etc. This arrangement ensures that the patient is not disturbed by conversation or by the noise made by the apparatus and its switches; it ensures stable conditions of examination.

The patient, the electrodes and the leads can pick up *alternating-current interference*. The balance control of the apparatus cannot eliminate all kinds of interference, and compensation is insufficient for very powerful disturbances.

There are three types of interfering fields, viz.:

1. High-frequency interference caused by diathermy apparatus or commercial radio transmission in the vicinity of the EEG room. Screening by means of a Faraday cage is necessary when diathermy apparatus (whether of the short-wave or high-frequency type) is in use within 50 m of the EEG room or when commercial broadcasters are within a radius of 500—1000 m.

2. Interference from a mains alternating current by capacity transmission.

Power circuit wiring in or on the walls of the EEG room, when insufficiently insulated, may cause leakage currents in the walls, and the charges can be transmitted to the patient. This often happens in older buildings with an insulation of unknown quality. Such alternating current fields can only be neutralized by partial, or preferably complete, screening by conducting surfaces connected to the frame of the apparatus (earth socket).

3. Interference from mains alternating current transmitted by induction.

These cannot be neutralized by conducting metal sheets or a Faraday cage. They are electromagnetic alternating fields forming around the current flowing in power circuits (main supply cables for buildings, supply lines for high-power motors, electric fires, electric kitchens, etc.). They induce alternating voltages in leads and cables which escape the balance control of the apparatus. Screening of all connections by steel-armoured tubing is theoretically possible and advisable but does not completely prevent these disturbances of induction. The minimal distance between patient and power circuits should therefore be 10 m. One must either select a suitable room or remove power wiring conducting currents above 5 A, the above mentioned minimal distance away from the room.