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Recording of physiological data on the magnetic tape: application in work physiology and hygiene

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Although the recording on the magnetic tape was originally developed for recording of sound, it is used to-day in many applications in technical, biological and medical research. The magnetic recording has many advantages for these applications: the signal may be re-played immediately after it was recorded (no developing process is needed), the re-playing does not affect the quality of the record, the unnecessary record may be simply erased and the recording material used again, etc. – During the last years a great progress in the technique of magnetic recording was reached: the use of high-quality material together with the improvement of the driving mechanisms has increased the upper frequency limit to several Mc/s, the precise construction of some instruments enables simultaneous recording of several tens of channels, for special purposes very small and light devices are manufactured.

In medical research the recording on the magnetic tape has been used almost exclusively for recording of bioelectrical phenomena, mainly for various types of analysis of the electroencephalogram. An advantage of this method is that the magnetic tape with the record may be transferred to another laboratory, which is equipped with the appropriate analyser. By means of the magnetic recording of the E.E.G. an international collaboration in the research of conditioned electroencephalographic patterns in man (*Gastaut* et alii, 1957) was realized. The importance of the magnetic recording technique was stressed and the minimum technical requirements for a device, suitable for research in electroencephalography, were proposed by Prof. *Grey Walter* on the 3rd Internat. Congress of Electroencephalographers in Bruxelles (*Walter*, 1958). – When a record on the magnetic tape is re-played faster or slower than it was recorded, all frequencies of the signal are increased or decreased by a constant factor: this procedure may be useful for some methods of analysis or recording, e.g. for the recording of fast bioelectrical phenomena by an ink-writing recorder.

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Many types of the instruments mentioned above are very big and expensive, nevertheless also small and inexpensive tape recorders designed for recording of sound signals – single track or stereophonic – may be very useful in physiological research, especially in various branches of the applied physiology.

The physiology of work has up to-day studied mainly the problems of physical strain. Nowadays the development of mechanisation and automation decreased the amount of physical strain, while on the other hand the amount of work needing mental concentration and complex analytic activity of sense organs is still increasing. Therefore it is necessary beside the use of "classical" methods of physiology of work to investigate the function of the highest nervous centers by means of a set of physiological and psychological methods. – Many of these methods need the worker under examination to interrupt his work or even to leave the working place: this condition, however, sometimes makes impossible to observe the earliest stages of fatigue. It is therefore desirable to investigate various physiological functions (e.g. the neuromuscular coordination of the working movements or the vegetative functions) during the work: in this case the central nervous regulation of vital processes is studied in natural conditions of living and working. – In detail these problems were discussed in the paper by Horváth, Fischer, Formánek, Frantíková and Mikiska (1961).

From the technical point of view this research is based upon the continuous polygraphic registration of the investigated physiological functions. Some of the obtained records (e.g. the E.C.G., E.M.G.) are suitable for further automatical analysis (rate counting, integration, etc.). Sometimes this analysis may be made easier by means of recording on the magnetic tape, especially then, when the transport of the necessary equipment for analysis is difficult or when the analysis is to be performed in another laboratory than that which is concerned with the field research.

It is obvious that the recording of physiological functions on the magnetic tape may be usefully exploited also in the laboratory research in occupational medicine, for the study of the effect of various physical or chemical factors in experimental subjects or animals (for automatical analysis of bioelectrical data, etc.).

The choice of an adequate system of magnetic recording depends on the signal to be recorded, i.e. on its frequency spectrum and on the necessary signal-to-noise ratio. The systems of "direct recording" (where the signal after amplification, after passing frequency filters and after superposition of supersonic oscillations – which is necessary for linearizing the magnetisation characteristic – is fed directly to the recording head) may not be used for signals including frequency components in the range 10^{-1} – 10^{0} c/s (e.g. the electrocardiogram or the electroencephalogram): for recording of such signals a modulated carrier frequency is to be used.

In this paper following problems will be discussed:

1. The comparison of the various systems of recording of physiological data on the magnetic tape (including their convenience for different kinds of bioelectrical potentials: E.C.G., E.M.G., E.E.G.).

2. The description of a transistorized frequency modulator and demodulator for magnetic recording designed by us for use in occupational medicine.

"Direct recording" of bioelectrical phenomena

The current types of the magnetic recorders are designed for recording of the sound; their frequency range extends therefore from several tens to several thousands c/s. This frequency range allows to use them for "direct" recording of some bioelectrical phenomena: electromyogram, action potentials of nervous fibres and cells, etc. The circuit diagram of the arrangement is presented in Figure 1: The picking-up electrodes are connected to the preamplifier, whose function is not only to amplify the bioelectric voltage, but also to eliminate various spurious potentials (e.g. the interference from the electromagnetic field originating in the mains supply). Usually a symmetrical preamplifier with the differential input (*Matthews* 1934, *Tönnies* 1938, *Dickinson* 1950, *Hill* and *Parr* 1950, *Vodolazskij* 1952, *Haapanen* 1953, *Kozevnikov* and *Soroko* 1957, etc.) is used. The output of the preamplifier is connected with the input of the tape-recorder. The possibility of the continuous control on the screen of a cathode ray oscilloscope is convenient, although not necessary. – When the signal is re-played, it may be observed visually, recorded or analysed.

The technique of "direct recording" of bioelectrical phenomena on a conventional tape recorder is suitable for neurophysiological experiments, in which action potentials arising without relation to a definite stimulus are to be studied for a long time: during re-playing they may be easily counted, selected according to their amplitude etc. (*Bures* 1958, *Beranek* 1959, *Porszasz* and *Szabo* 1959).

Although it is impossible to reproduce the direct component and the lowest frequencies by means of a conventional re-playing head (the voltage generated in the re-playing head is proportional to the first derivative of the magnetic remanence with respect to the time), the low frequency response of the recording system may be improved in two ways.

1. *Coaton* (1954) connected the recording head (i.e. an inductive load) to an amplifier with a low output resistance: the recording current and the magnetic remanence of the tape is then approximatively proportional to the integral of the recorded signal. – This system enables the distortion-free recording of the action potentials of nerves, etc., but is more complicated than the modulation systems of record.

2. Another way to improve the reproduction of the low frequencies is to re-play the record considerably faster than it was recorded. Either a sample of the record is made into a belt (*Shaper* 1945, etc.) or the magnetic tape is re-played by means of heads fixed on a rotating drum (*Drechsler* and *Krecan* 1957, *Krecan* 1959); the movement (of the tape or of the drum) is synchronized (e.g. photoelectrically) with the time-base of a cathode ray oscilloscope. An instrument with the rotating drum designed for use in clinical electromyography is commercially available (*Magnoscope-Chirana*, Prague); because the re-playing on this instrument does not need cutting off the magnetic tape, it is especially suitable for field research, for student laboratories, etc.

Systems of magnetic recording using modulated carrier frequency

Two different types of the modulation systems of magnetic recording must be discussed separately: systems recording on every track one channel (i.e. one carrier frequency) only and systems recording several channels (several carrier frequencies) on one track.

For multi-channel recording the devices of the first type need a multi-track tape recorder to be used; simple modulator and demodulator circuits, however, are sufficient and a large frequency range of the modulated carrier frequency is available. The last mentioned fact (and also the absence of cross-modulation effect) enables to obtain in general better frequency characteristics and signal-to-noise ratio (s:n) than those of the systems recording several channels on one track.

The systems recording several channels on one track enable, on the contrary, the use of a simple recorder and the inexpensive standard recording material.

The technical parameters of various modulation systems of magnetic recording were reviewed in the paper by Mikiska (1961). In this paper we shall present only brief notes about the technical details. – The systems recording one channel on one track will be discussed at first.

Amplitude modulation of the carrier frequency

For the amplitude modulation of the carrier frequency (AM) a narrower frequency band than for frequency modulation of the carrier frequency (FM) is necessary (for equal values of the carrier frequency and the maximal frequency of the modulating signal); this advantage is important, however, mainly for recording of several channels on one track. – Another advantage of the amplitude modulation is the low sensitivity of the system to variations in the speed of the magnetic tape (*Walter* 1959).

The most important disadvantage of the AM systems of magnetic recording is the low signal-to-noise ratio (s:n). In our preliminary experiments with small tape recorders and conventional magnetic tapes (designed for recording of sound) even with almost 100% modulation the s:n of not more than 10:1 (in the frequency band 0–100 c/s) was obtained[1].

We conclude therefore, that the use of AM for recording of low frequencies on small tape recorders designed for recording of sound is not suitable.

Frequency modulation of the carrier frequency

The mathematical theory of the frequency modulation (*Nichols* and *Rauch* 1956) is more complicated than that of the amplitude modulation. The broader frequency band (with respect to AM) is not a disadvantage, when only one channel is to be recorded on one track. A frequency deviation as large as possible is to be used: the ratio of the signal to the noise and to other interfering potentials, e.g. those caused by variations in the speed of the tape) is directly proportional to the frequency deviation[2].

A very important advantage of the frequency modulation of the carrier frequency for recording on the magnetic tape is that the harmonic distortion, inhomogenity of the recording material and other factors, affecting the amplitude and waveform of the reproduced carrier frequency, have negligible effect on the demodulated signal. (The reproduced modulated carrier is passed through an amplitude limiter before the demodulation.) Among other modulation systems only the impulseduration modulation is equally insensitive to instability of the amplitude and the harmonic distortion of the reproduced oscillations.

As has been already mentioned, the noise of the magnetic tape manifests itself mainly in the fluctuations of the amplitude of the reproduced oscillations. Therefore the signal-to-

[1] We do not know any paper presenting the mathematical theory of the influence of the noise of the magnetic tape on AM and FM recording systems. The mathematical theory of the noise of the radio-frequency transmission line (*Nichols* and *Rauch* 1956) may not be applied on this problem, because the noise of the magnetic tape (which is due mainly to its inhomogenity) is approximately proportional to the magnetic remanence. Therefore it results mainly in the fluctuations of the amplitude of the recorded oscillations. When these fluctuations do not exceed 10–20%, they do not manifest themselves as deterioration in the quality of the reproduced sound.

[2] The variation in the speed of the magnetic tape results in a spurious frequency modulation of the carrier. The ratio of the signal to the resulting interfering potential is equal to the ratio of the frequency deviation to the maximal value of the speed variation. This interference may be compensated, when an unmodulated frequency is recorded on another track (*Young* 1953, *Marchand* 1953, *Nichols* and *Rauch* 1956).

noise ratio of the FM systems of magnetic recording is in general much larger than that of the AM systems. – With the same small tape recorders and conventional magnetic tapes (which were quite unsuitable for AM recording) signal-to-noise ratio more than 50:1 in the frequency range 0.5–800 c/s was obtained (by means of the frequency modulation system described in the second part of this paper).

The FM recording systems have been extensively used in physiological and clinical research. *Liberson* and *Smith* (1955) recorded seven channels of the E.E.G. on a multitrack Ampex recorder; slow re-playing of the record enabled the recording of fast electroencephalographic patterns (which are important when the potentials are led off by means of implanted subcortical electrodes) with an ink-writing oscillograph. – A system suitable for recording and subsequent automatical analysis of one channel of the E.E.G. was designed by *Cox, Obrist* and *Henry* (1955).

The use of a storage device, such as the tape recorder, is essential for the correlation analysis of the E.E.G.: this type of automatical analysis may not be performed without the possibility of reproducing the signal many times. The methods of the correlation analysis are discussed in the papers by *Brazier* and *Casby* (1952), *Barlow* and *Brazier* (1954), *Brazier* and *Barlow* (1956) etc. A multi-channel recording system for the correlation analysis of the E.E.G. was designed by the workers of the Massachussetts Institute of Technology (*Brown, Barlow, O'Brien, Peake* and *Geisler* 1959). – The problem of the detection of the evoked responses on the background of large potentials of the spontaneous E.E.G. may be solved by the methods and the technique of correlation analysis (*Barlow* 1957, etc.). – Also other types of automatical analysis of the E.E.G. have been performed by means of the FM magnetic recording systems (*Burch, Silverman* and *Greiner* 1956, *Burch* 1959 etc.).

Simple and versatile two-channel devices for recording of fast bioelectrical phenomena with ink-writing oscillographs by means of FM recording on the magnetic tape and slow replaying of the record are manufactured by several producers.

Impulse-duration modulation

A system for recording of the E.E.G. on the magnetic tape by means of the modulation of the duration of impulses was designed by *Kuiper* (1960). This system needs the whole frequency band of one track for recording of one channel. – As the impulse-duration system of magnetic recording (like the FM system) is used, factors, affecting the amplitude and waveform of the reproduced oscillations (harmonic distortion, noise and inhomogenity of the tape, variations in the gain of the reproducing amplifier of the tape recorder, etc.) have little effect on the demodulated signal. The modulator and demodulator circuits are very simple. – An advantage of the impulse-duration system (in comparison with the FM system) is that variations in the driving speed of the magnetic tape have very little influence on the reproduced signal.

Recording of several channels on one track

Systems of this type have been rarely used in physiological research. *Bekkering* (1956) used a system of amplitude modulation for recording of eight channels of the E.E.G. and of one speech channel on a single track. This device was used for the investigation of conditioning of E.E.G. patterns in man (*Gastaut* et alii, 1957), that has been already mentioned above. – A frequency modulation system of recording of two channels of the E.E.G. on a single track was designed in the Burden Neurological Institute (*Walter* 1959).

Requirements to the system of magnetic recording with respect to the problems of occupational medicine

The basic requirements to a system suitable for investigation in occupational medicine, especially for field research, are simplicity, reliability, low weight and energy consumption and the possibility of recording various types of signal.

The lower limit of the frequency band should be at least 0.5 c/s, i.e. the overall time constant should be not less than 0.3 sec. This value of the time constant is sufficient for distortion-free recording of the normal human E.C.G. When E.C.G. abnormities, characterized by large slow waves (e.g. ventricular extrasystoles, some types of heart blocks, etc.), occur, they can be easily found out in the record re-played from the magnetic tape, although their exact analysis must be performed by means of recording on an electrocardiograph, whose time constant is at least 1 sec. The recording of the E.C.G. during the work on a magnetic tape recorder using a modulation system whose overall time constant is 0.3 sec.[1] is therefore quite satisfactory for the occupational medicine. – The upper frequency limit should be several hundred c/s, which is necessary for distortion-free recording of the electromyogram, led off from the electrodes applied on the skin.

The requirements of low weight and energy consumption may be fulfilled by the use of a single-track or stereophonic tape recorder with the speed of the tape 9.5 or 19 cm (3.75 or 7.5)″ per sec., designed for recording of sound. Frequency modulation of a carrier frequency in the range of several kilocycles per sec. or an impulse-duration system of modulation may be an adequate solution of the problem. The fact of the insensitivity of these systems to harmonic distortion and variations in the amplitude of the re-played oscillations and the simplicity of the modulator and demodulator circuits make also these systems suitable for research work in occupational medicine.

A transistorized frequency modulator and demodulator for magnetic tape recording, designed by us for use in occupational medicine, will be described in the second part of this paper.

Application of the magnetic recording in occupational medicine: description of a frequency modulator and demodulator

The schematic diagram of the arrangement is presented in Figure 1: The picking-up electrodes are connected to the input of the preamplifier, whose functions have been already discussed above. The output of the preamplifier is connected to the input of the frequency modulator (i.e. the generator of frequency-modulated carrier frequency). The output of the frequency modulator is then connected to the input of a tape recorder. During re-playing the modulated carrier frequency is fed to the input of the frequency demodulator; the demodulated signal is led from the output of the demodulator to the input of the devices for registration and for automatical analysis.

[1] When the time constant is shortened below 0.3 sec., the first visible distortion of the E.C.G. waveform, which could be misinterpreted as pathological condition, is the depression of the isoelectric line in the interval ST.

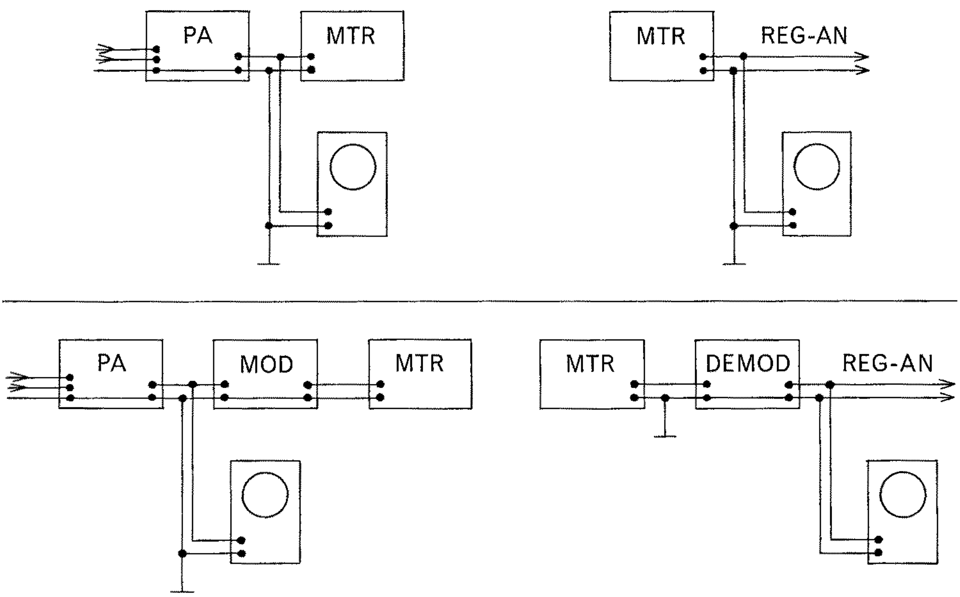

Figure 1 *Schematic diagram of the direct recording (above) and of the frequency modulation recording system (below).* PA = preamplifier, MTR = magnetic tape recorder, MOD = modulator, DEMOD = demodulator, REG-AN = output for registration and analysis. For continuous control of the recording and re-playing a cathode ray oscilloscope is used.

Instead of a special preamplifier of the bioelectrical potentials the preamplifier of an electroencephalograph or electromyograph may be used. Input plugs for the connection to an E.E.G. or E.M.G. apparatus are provided in the modulator circuit.

Special care must be taken for correct grounding of the devices used for magnetic tape recording of bioelectrical potentials: as so during recording as during the re-playing of the record. The general rules for correct grounding of electrophysiological instruments have been explained by many authors (*Holzer* 1930, *Schaefer* 1940, *Dickinson* 1950, *Vodolazskij* 1952, *Whitfield* 1957, *Beránek* 1959, etc.). A convenient grounding for the recording arrangement, using a special preamplifier and registration by means of a cathoderay oscilloscope, is presented in Figure 1. When the preamplifier of an electroencephalograph is used, the grounding of the chassis of this instrument, as it is commonly used, may be sometimes satisfactory. Sometimes, however, it is more convenient to connect both the chassis of the electroencephalograph and the grounded input plug of the magnetic tape recorder to the common ground lead. We have designed a special switching box for connecting of the E.E.G. apparatus, the modulator and the tape recorder, which is described in Figure 2 (indicating also the grounding of the instruments). With the switch in the upper position it is

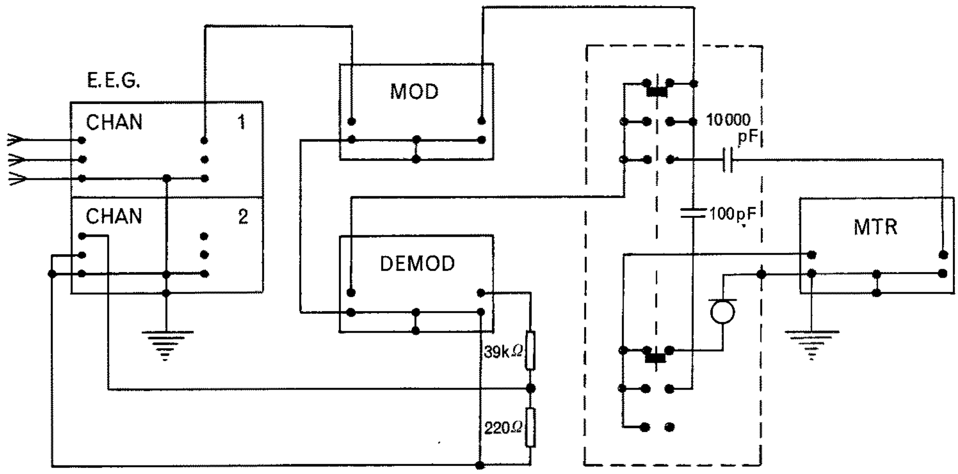

Figure 2 *Schematic diagram of the connection of the FM recording system to an electroencephalograph.*

possible to record (by means of the microphone) the data of the experiment on the magnetic tape. The middle position of the switch is proposed for recording of the bioelectrical potential; the correct function of the modulator may be observed in the record of the channel two of the E.E.G. The lower position of the switch is used during re-playing of the record.

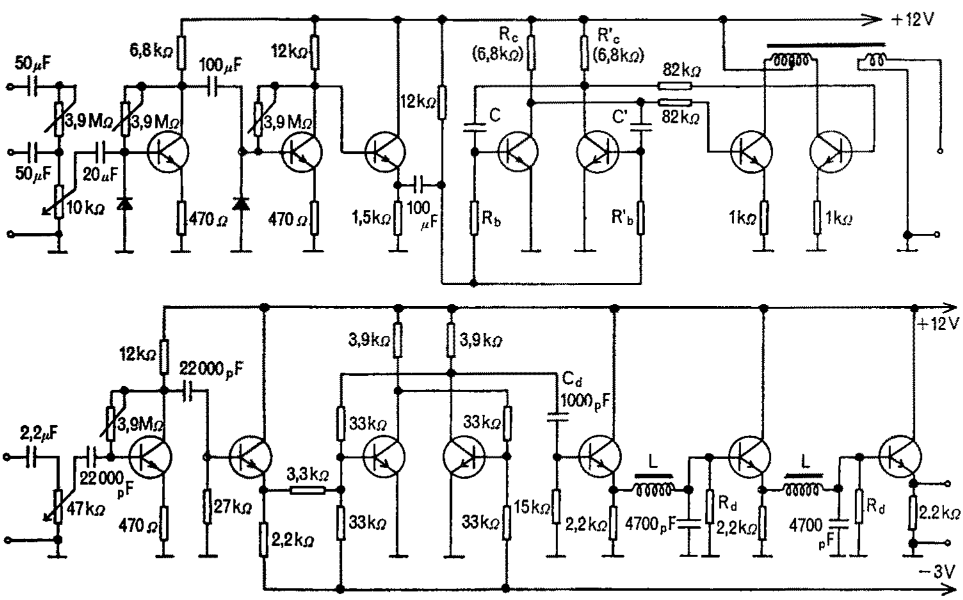

Figure 3 *Wiring diagram of the frequency modulator (above) and demodulator (below).* Transistors: 103 NU 70 or 104 NU 70 (n-p-n, W_c = max. 50 mW, U_{ce} = max. 20 V). Germanium diodes: 3 NN 71 ($U_{inv.}$ = max. − 60 V). Any reliable transistors and diodes may be used in the circuits; if p-n-p-transistors are used, the polarity of the diodes and supplies is to be reversed.

Operation and adjustment of the frequency modulator

The upper input plug is designed (Figure 3) for connection to the plate of the third amplifying stage or to the grid of the fourth amplifying stage of an electroencephalograph or electromyograph. The adequate frequency deviation for the maximal signal amplitude is adjusted by means of the potentiometer 3.9 Megohms. – The lower input plug is designed for connection to a cathode follower stage: approximately 20 mV R.M.S. of the input signal are necessary for the frequency deviation $\pm$ 40%, which is the maximal one ensuring sufficient linearity of the frequency modulation. (See also Figure 4.)

The first two transistors operate as amplifying stages. The unblocked resistor 470 ohms in the emitter lead increases largely the input resistance of the stage (which is necessary for the increase of the time constant of the R-C coupling, unless extremely high coupling capacities are to be used) and decreases the dependence of the gain of the stage on the supply voltage and the transistor parameters. (When the supply voltage was decreased from 12 V to 8 V, the decrease in the voltage gain of the stage was no more than 2,5%.) The po-

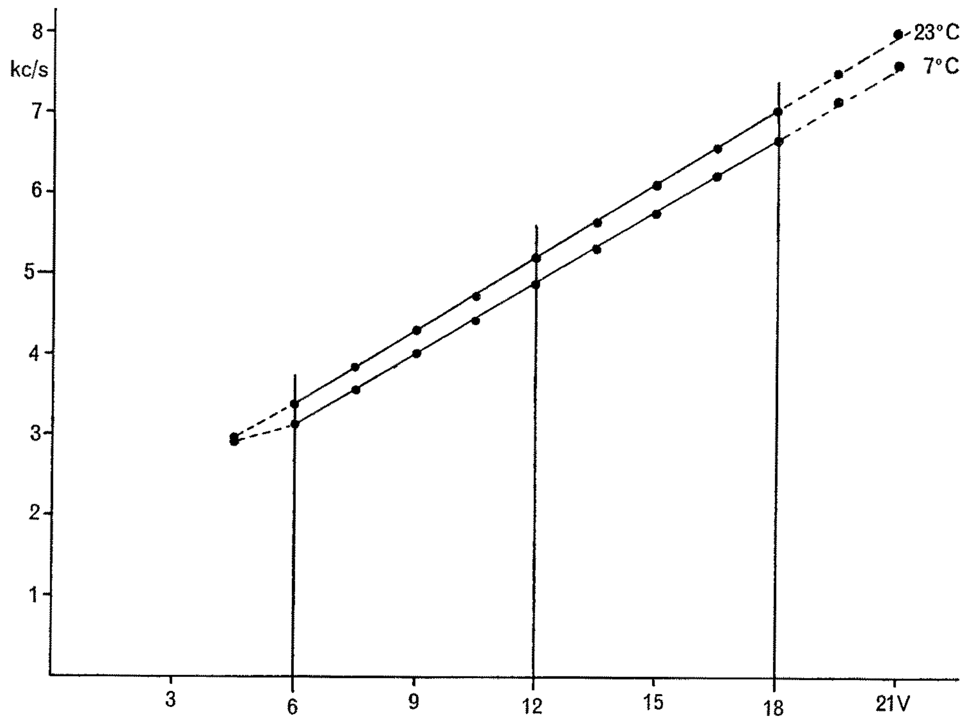

Figure 4 *Modulation characteristic of the frequency modulator.* Measured at temperatures 7 and 23° C. Further explanation in the text.

tentiometer 3.9 Meghoms placed between the basis and collector is adjusted so, that the potential difference collector – ground equals (in absence of the signal) approximately the half of the supply voltage. The stabilisation of the collector current is sufficient for the environment temperature 5°–30° C; no dependence of the voltage gain on the temperature was observed in this temperature range.

The germanium diodes shorten the time during which the amplifying stages are blocked after passing of a large signal (e.g. a movement artefact): The time constant of the capacitive coupling is determined under conditions of normal operation by the input resistance of the following stage. When, however, this stage is blocked, i.e. the basis becomes negative with respect to the emitter, the time constant is greatly increased (because it is determined by the value of R_b, which is much larger than the input resistance of the stage). The insertion of the germanium diodes (which is quite ineffective under condition of normal operation) reduces therefore considerably the time constant of the stage in the blocked state and the duration of blocking.

The third transistor operates as an emitter follower, directly coupled to the second amplifying stage.

The fourth and the fifth transistors operate as a symmetrical multivibrator circuit. The frequency of its oscillations is controlled by the voltage to which the basis-leaks (R_b) are connected, i.e. the amplified input voltage. A matched pair of transistors with approximately equal characteristics (mainly equal values of collector-to-emitter short-circuit current gain β) is to be used. To obtain the maximal range of linearity following adjustment of the circuit is necessary:

Either the value of R_b is calculated from the formula $R_b = \beta \cdot R_c$ or variable resistors are inserted instead of R_b (before the joining of the capacitors C and C′). The variable resistors are adjusted, until the potential differences between the ground and the collectors U_{ce} and U'_{ce} (in absence of the signal) equal several tenths of volt. Then equal capacitors $C = C'$ (approximately 1000 pF) are inserted and the oscillation frequency in absence of the modulating signal is measured. The desired carrier frequency is then obtained by replacing the capacitors C and C′ by the correct values calculated from the relation of the inverse proportionality of the oscillation frequency on the capacities C and C′. – The modulation characteristic of a model (with following values of components: $R_c = 6{,}8$ kiloohms, $\beta = \beta' = 22$, $R_b = 150$ kiloohms), i.e. the oscillation frequency (Y) as a function of the voltage, to which the basis-leaks are connected (X), is presented in Figure 4.

The only effects of temperature change from 7° C to 23° C is a shift of the oscillation frequency (which is important only when the direct component should be recorded) and an increase in the slope of the modulation characteristic by about 3%.

The sixth and seventh transistors operate as a symmetrical amplifying stage. They separate the output plugs from the multivibrator circuit. The transformer coupling suppresses the higher harmonics of the multivibrator which otherwise would cause beating with the oscillations of the supersonic bias in the tape recorder.

Operation and adjustment of the demodulator

The first transistor operates as an amplifying stage; the potentiometer 3.9 Megohms is adjusted in the same way as in the amplifying stages of the modulator. The second transistor operates as an emitter follower stage.

The third and fourth transistors operate as a trigger circuit, which transforms the oscillations re-played from the tape recorder into the rectangular waveform. A matched pair of transistors with approximately equal characteristics is to be used. A differentiating circuit formed by the capacitor 1000 pF and the resistor 16 kiloohms follows.

The fifth transistor operates as an emitter follower without any D.C. bias of the basis. Therefore only positive impulses (resulting from the differentiation of the rectangular waves) can pass through this stage, while the negative impulses are suppressed. The amplitude and duration of these exponentially decaying impulses depend only on the values of the components and the supply voltage of the demodulator, while their frequency is equal to that of the oscillations replayed from the tape recorder. Therefore the original modulating signal may be obtained by means of a low-pass filter.

In the described demodulator two L-C filters are used, separated by the sixth transistor (each from the other) and by the seventh transistor (from the output). The sixth and seventh transistors operate as directly coupled emitter followers; the D.C. bias of the basis is obtained by the direct component of the impulses. The resonance of the L-C filters is damped by the input resistance of the transistor stages and by the damping resistances R_d which are placed in parallel. The correct damping must be adjusted in the following way: For the sake of simplicity transistors with equal β are used for the sixth and seventh stages (to obtain equal input resistances of these stages). Instead of R_d potentiometers are inserted. The capacitor in the differentiating circuit C_d is disconnected and the basis of the fifth transistor is connected to the output of an audio-frequency sinewave generator through a dry cell providing the necessary D.C. bias. The overall frequency characteristic of the fifth, sixth and seventh transistor stages is then measured with various valued of R_d: the correct characteristic is that without no marked increase of the amplitude at the resonant frequency of the L-C filters and with the steep decrease of the amplitude when the frequency is raised above that resonant frequency. – When a square wave generator is available, it may be connected to the basis of the fifth transistor in the same way: the adjustment of the damping resistance R_d is still more simple (minimal distortion of the shape of the rectangular waves).

In our model of the demodulator the values of R_d were 120 kiloohms, the inductance L was approximately 10 Henry, the resonance frequency of the L-C filters was approximately 735 c/s.

The overall characteristics of the recording system

The overall frequency characteristics of the recording system (preamplifier + frequency modulator + demodulator + registration device) do not depend only on the characteristics of the modulator and demodulator. When, however, the registration during re-playing is performed on a cathode-ray oscilloscope with a D.C. broad band amplifier, the influence of the registration system on the overall characteristics may be neglected.

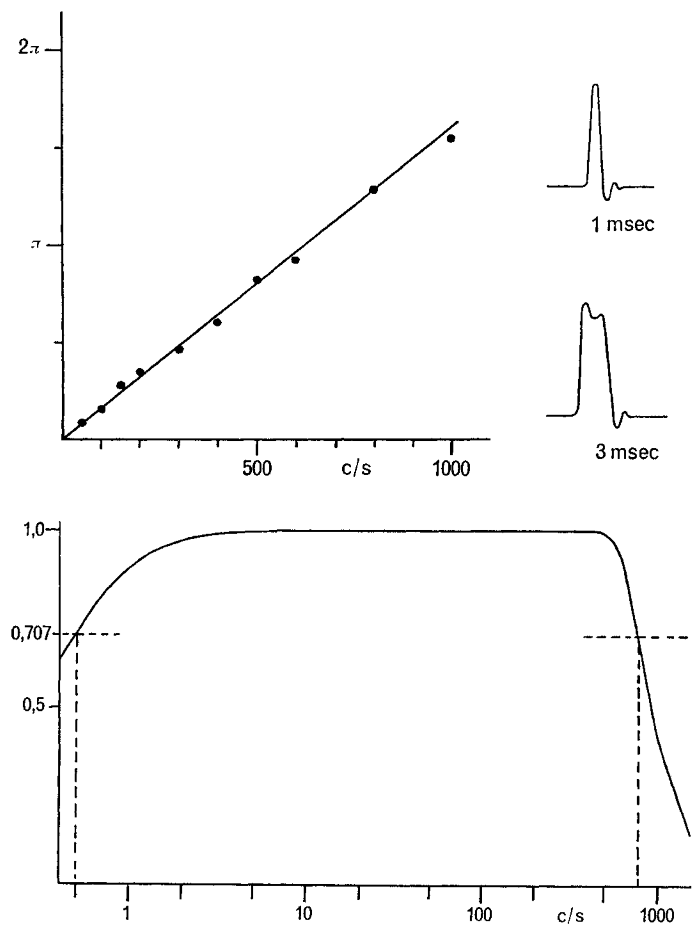

Figure 5

Overall characteristics of the recording system. Below: amplitude frequency characteristic (X – frequency, logarithmic scale, Y – amplitude gain, linear scale). Above: phase frequency characteristic (X – frequency, linear scale, Y – phase shift, linear scale). Right: response of the recording system to rectangular impulses of the duration 1 msec. and 3 msec.

The overall frequency characteristics of our model of the modulator and demodulator, in connection with the first three amplifying stages of one channel of an electroencephalograph used as the preamplifier, are shown in Figure 5. The band control settings of the E.E.G. channel 1,0 sec. (for the time constant) and 2000 c/s (for the high-frequency filter) have been used. The overall time constant of the recording system was approximately 0.3 sec. The amplitude frequency characteristic showed a fall of 3 dB (i.e. to 0.707 of the amplitude gain for the middle frequencies of the band) at the band limits 0.5 and 800 c/s. – When the waveform of the signal is to be reproduced without distortion, it is necessary the phase shift to be directly proportional to the frequency in the respective frequency range. As the phase frequency characteristic in Figure 5 shows, this condition is fulfilled up to 800 c/s. – The response of a system at the upper limit of its frequency range is easily demonstrated by its response to a rectangular impulse. This response of our recording system is also indicated in Figure 5 for rectangular impulses of the duration 3 msec. and 1 msec.

As has been mentioned above, the ratio of the signal to the spurious potentials depends mainly on the noise of the tape and the variations of the driving speed of the tape. This ratio was larger than 50:1 (in the whole frequency range 0.5–800 c/s) with the use of the described modulator and demodulator, of the tape recorders "Sonet" (speed of the tape 9.5 cm–3.75″ per sec.) or "MF 2 Supraphon" (speed 19 cm – 7.5″ per sec.) and with the magnetic tape Agfa CH.

The temperature stability of the recording system has been already discussed: it is sufficient in the range from 5° C to 30° C. The temperature range of operation might be greatly extended by use of special components (silicium transistors, etc.)

Examples of records

The Figures 6, 7 and 8 present a comparison of the original record of the bioelectric potential (A), of the same potential passed through the modulator and demodulator (B) and of the bioelectric potential re-played from the magnetic tape (D). In these figures also time-marks during recording on the magnetic tape (C) and during re-playing (E) are presented. In Figure 6 a human electroencephalogram was recorded, in Figure 7 a human electromyogram recorded from the electrodes applied on the skin (i.e. a summation electromyogram), in Figure 8 a normal human electrocardiogram. In all these types of the bioelectric potentials the use of the described frequency modulator and demodulator for recording on the magnetic tape is quite adequate[1].

Acknowledgement: I am greatly indebted to Dr. *H. Mikisková* for valuable help in this work and to Ing. *F. Bartos* (Department of Neurophysiology, Palacky University, Olomouc) for critical notes on the circuit design.

[1] The possibility of recording of abnormal E.C.G. waveforms with a system, whose time constant is 0.3 sec., has been already discussed above.

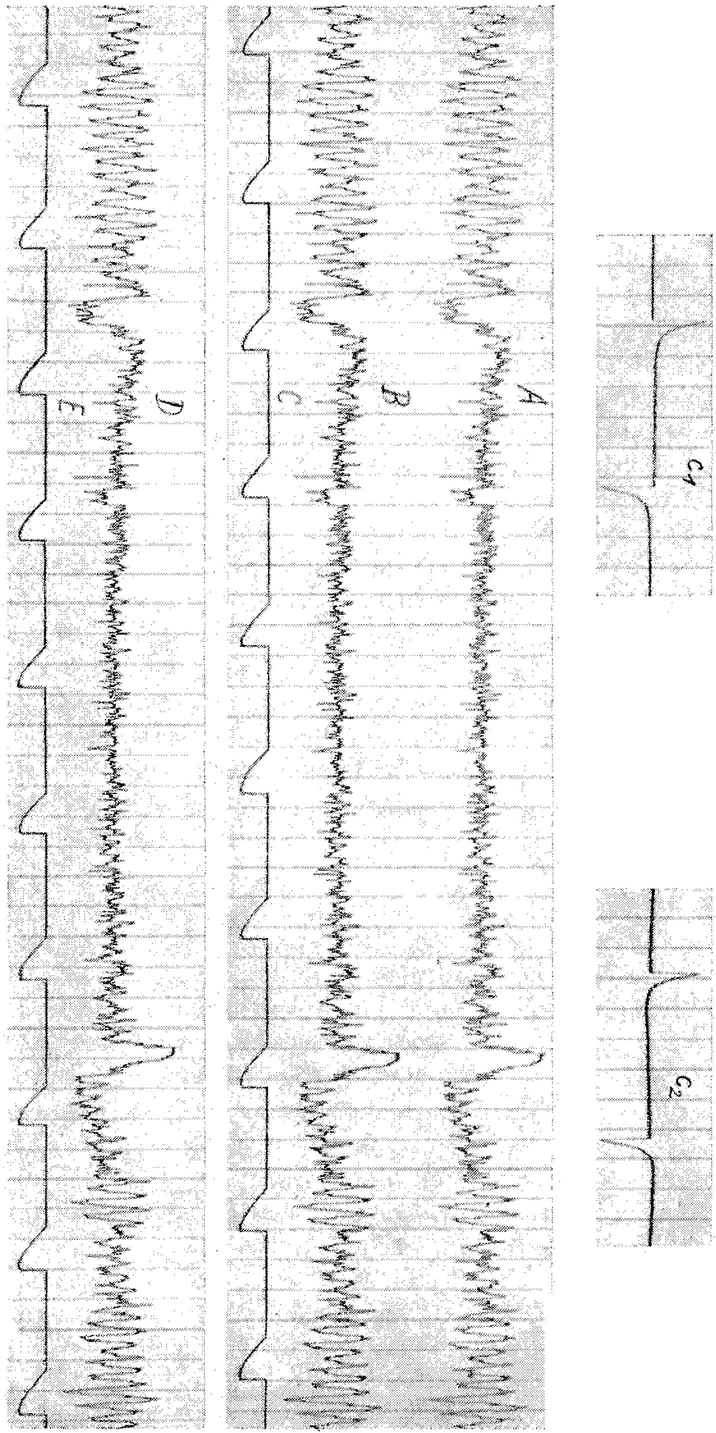

Figure 6

Record of a human E.E.G. Adult healthy female, right frontooccipital derivation, opening and closing of the eyes. (Eye movement artefacts and blocking of the alpha rhythm are present.)
A: original record.
B: the same signal passed through the modulator and demodulator,
C: time-mark during recording.
D: the signal re-played from the magnetic tape.
E: time-mark during re-playing. c_1: calibration impulse 50 microvolts, original record. c_2: the same calibration impulse re-played from the magnetic tape.

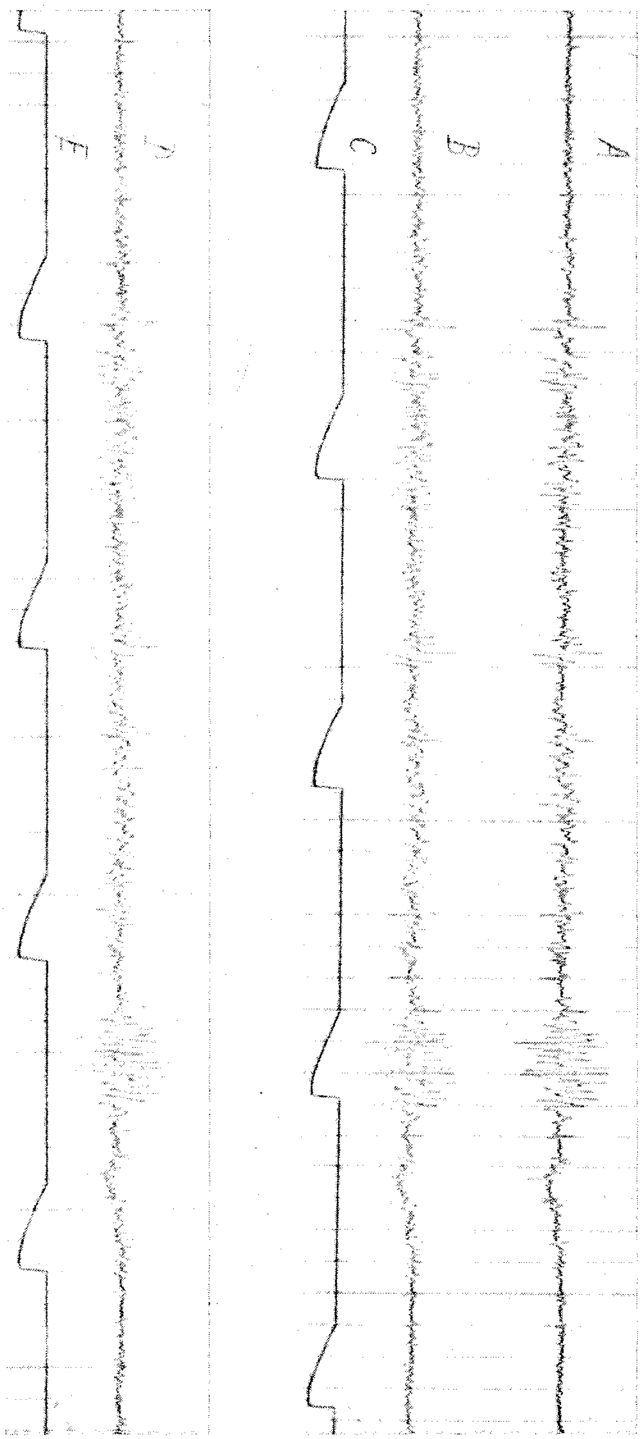

Figure 7

Record of a human E.M.G. Adult healthy female, bipolar recording, electrodes applied on the skin over the belly of m. extensor digitorum longus antebrachii dx. (during typewriting). Abbreviations as in Figure 6.

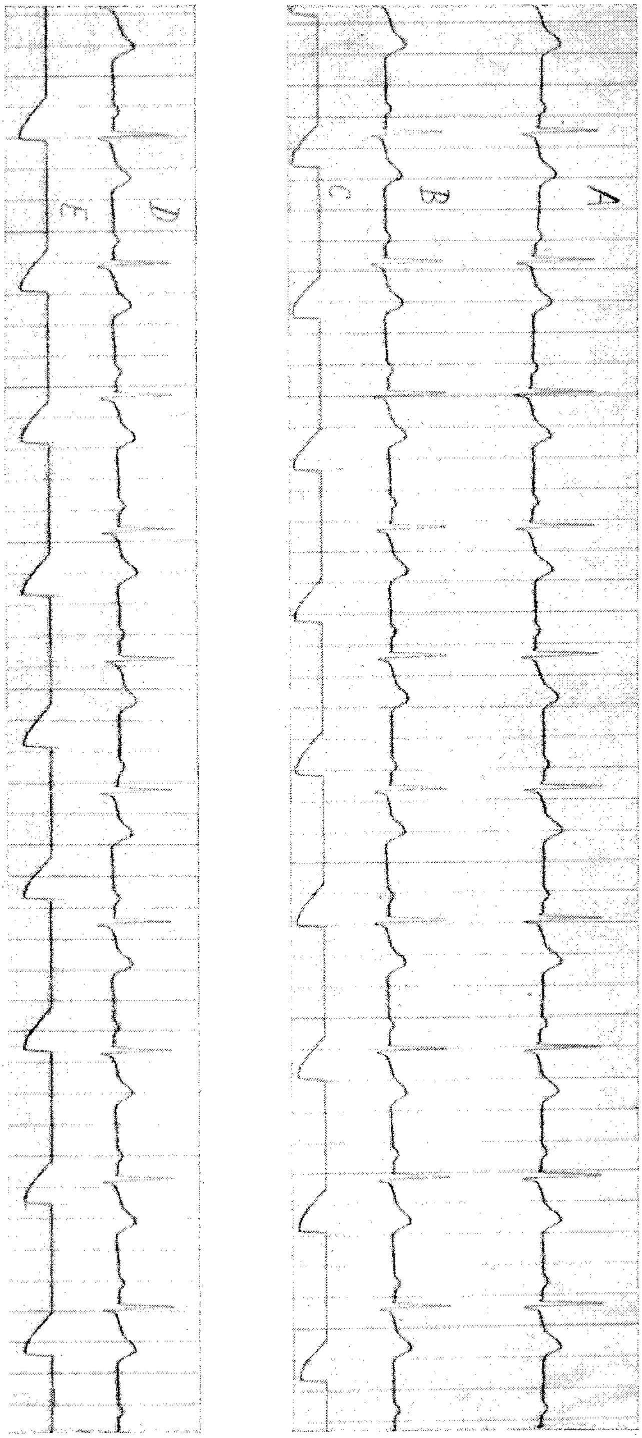

Figure 8

Record of a human E.C.G.
Adult healthy female,
II. standard derivation.
Abbreviations as in Figure 6.

Summary

The recording of physiological data on the magnetic tape is suitable 1) when automatical analysis of the experimental data should be performed in another laboratory or 2) in field research, when the transfer of an appropriate recorder or analyser is difficult. – Various possibilities of the use of magnetic recording, especially in the occupational physiology and hygiene, are discussed. "Direct recording" of the physiological data (on a conventional tape recorder, designed for recording of sound) is possible only for some kinds of signal, e.g. the E.M.G. or action potentials of nerve and muscle cells or fibres. When signals, including frequency components in the range of several c/s are to be recorded (e.g. the E.C.G. or E.E.G.), it is necessary to use a modulated carrier frequency for recording. Technical parameters of various modulation systems of recording are compared. The requirements on a system of recording for research in work physiology and hygiene are proposed. – In the second part of the paper a transistorized frequency modulator (carrier frequency 5000 c/s, frequency deviation $\pm$ 40%) and a transistorized demodulator are described. In connection with a small conventional magnetic tape recorder they enable to record a signal in the frequency range 0.5–800 c/s ensuring the signal-to-noise ratio more than 50:1; examples of records of E.E.G., E.M.G. and E.C.G. are presented.

Zusammenfassung

Die Magnettonbandaufnahme physiologischer Daten eignet sich: 1) wenn eine automatische Analyse der Daten in einem anderen Laboratorium durchgefuhrt werden soll oder 2) wenn bei einer Untersuchung im Betrieb der Transport eines geeigneten Registriergerätes oder Analysators schwierig ist. Verschiedene Möglichkeiten der Verwendung der Magnettonbandaufnahme, hauptsächlich im Gebiete der Arbeitsphysiologie und Hygiene, sind besprochen. Die «direkte Aufnahme» physiologischer Daten (an einem für Schallaufnahme konstruierten Gerät) ist nur fur einige Typen des Signals möglich, zum Beispiel für den E.M.G. oder für Aktionspotentiale der Nerven- und Muskelzellen bzw. Fasern. Für die Aufnahme von Signalen, die Frequenzkomponenten im Bereiche einiger Hz behalten, muß man eine modulierte Trägerfrequenz verwenden. Technische Parameter verschiedener Modulationssysteme werden verglichen. Anforderungen an ein Aufnahmesystem fur arbeitsphysiologische und hygienische Untersuchungen werden vorgeschlagen. – Im zweiten Teil wird ein aus Transistoren konstruierter Frequenzmodulator (Trägerfrequenz 5000 Hz, Frequenzhub $\pm$ 40%) und ein Demodulator beschrieben. In Verbindung mit einem kleinen Magnettonbandgerät ermöglichen sie die Aufnahme eines Signals im Frequenzbereich 0.5–800 Hz mit dem Signal-Rausch-Verhältnis von mehr als 50:1. Beispiele der Aufnahmen des E.E.G., E.M.G. und E.K.G. werden angeführt.

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Psychologie et Accidents du travail[1]

Par *P. Andlauer*[2]

La forme particulière qu'a pris en France l'essor de la médecine du travail, a permis à un certain nombre de médecins qui sont au nombre actuellement de près de 4000 sur l'ensemble du territoire, de s'intéresser à des techniques préventives particulières qui ne répondent pas habituellement à la forme médicale classique.

Par ailleurs, il convient actuellement de considérer que la mortalité et la morbidité provoquées par les accidents, soulèvent un problème qui doit être traité de la même manière que les autres problèmes de la santé publique.

[1] Exposé fait le 30 novembre 1961 à Lausanne devant le groupement romand d'hygiène industrielle et de médecine du travail.

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