automatic data processing systems become sufficiently available to be considered as possible tools in an information-retrieval system. Thus the SEAC experiments indicate the practicality of using automatic data-processing systems for scanning a file of information at high rates. However, many mechanisms considerably simpler than an automatic data-processing system can also do such scanning, and the question remains open about the comparative advantages of an automatic data-processing system and simpler mechanisms for the actual process of looking at a properly organized file. In some retrieval situations, most notably in the Patent Office, the problem is of sufficient magnitude and complexity that the power of an automatic data-processing system to do more than just scan a file appears at first inspection to be a requirement. Where the machine system seems to offer a unique contribution is in the off-line jobs. For such functions as preparing a search prescription, editing a file, eliminating errors, transliterating from one code to another, exploring complex logical conditions imposed on the question and file, and probably many others, the automatic data-processing system offers the outstanding virtues of high speed and great versatility. Thus it is possible to use SEAC not only to test the utility of an automatic data-processing system for the Patent Office retrieval problem but also to study the performance of other devices by simulating them on SEAC. In the computing machine field it is a well-known phenomenon that machine users discover many new applications of these machines while they are in the process of using them. It is hoped that the experiments on SEAC will serve a similar purpose.

References and Notes

1. Because the search of Patent Office literature is such a complex task, we found particularly valuable the many informative discussions with members of the Office of Research and Development, U.S. Patent Office. In particular, their guidance helped to identify specific problem areas whose characteristics might be suited to machine processing and provided a background which led to a number of ideas that are contained in this article. In addition, fruitful discussions were held with Calvin N. Mooers of the Zator Co., whose helpful comments were derived from experience with related concepts in the field of information retrieval. The incentive to start on the computer search of chemical structures arose out of discussions with Ascher Opler of Dow Chemical Co. regarding his pioneering efforts with such techniques. Members of the Data Processing Systems Division of the National Bureau of Standards who contributed to the development of the results described here are Catherine E. Lester and Ethel C. Marden, who wrote the data-editing programs for SEAC, and Mary E. Stevens and Edwin K. Woods.
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Electronically Controlled Respirator

Randolph Batson, L. H. Montgomery, L. H. Beisel, David McCroskey, Sam L. Clark

The mechanical control of artificial respiration is customarily dependent upon devices regulated by an operator who adjusts the machine to supply an appropriate gas mixture, usually room air, at a previously determined rate, velocity, and volume. Although known norms and the reactions, subjective desires, and reflexes of the subject may be used to determine the effectiveness of the respiratory exchange, and although periodic chemical analyses of blood may offer further checks upon this, the patient or experimental animal has no direct control over the apparatus even though his nervous mechanisms are largely intact. Prolonged artificial respiration without frequent measure of arterial oxygen saturation, carbon dioxide tension, and blood *p*H may result in states of hyper- or hypoventilation.

The constant use of respirators by many patients with varying degrees of muscular paralysis following poliomyelitis emphasizes the need for some arrangement that would be less under outside control and more dependent upon the patient's normal physiological needs at any one moment. With this objective in mind, experiments were undertaken (*1*) to test the possibility of using the actual output of an animal's respiratory center as the source of impulses which would, through an appropriately designed electronic device, control mechanical respirators (*2*).

The first experiments were directed toward the utilization of the regular bursts of nerve impulses put out through the phrenic nerve in order to activate the diaphragm during the inspiratory phase of respiration. Because of technical difficulties, this plan was abandoned when it was found easier and more desirable to use potentials that accompany muscular contraction. Primary muscles of respiration such as the diaphragm or intercostals were found to be most effective in triggering the electronic device, but even minor accessory muscles such as the platysma or the small dilator of the dog's ala nasi have been used successfully, supplying effective control of respiration over periods of more than 48 hours in animals with high spinal transections. Successful control of respiration in anesthetized animals for many hours at a time has been readily obtained with needle electrodes in the ala nasi, the intercostals, or the diaphragm. Decerebrate cats have been maintained as long as 4 days without difficulty under electronic respiratory control.

Electronic Circuit

The electronic equipment was designed as shown in Fig. 1. It functions in the following way. Potentials from the muscle are picked up by 1- by 2-inch nickel silver electrodes on the surface of the skin or by needle electrodes implanted in the muscle and passed through an R-C filter to the input amplifier tubes. This stage of amplification is balanced so that it cancels in-phase voltages and amplifies the voltage difference between the two active electrodes. The combination of high-pass filter and degenerative

The authors are members of the departments of pediatrics and anatomy of the Vanderbilt University School of Medicine, Nashville, Tenn.

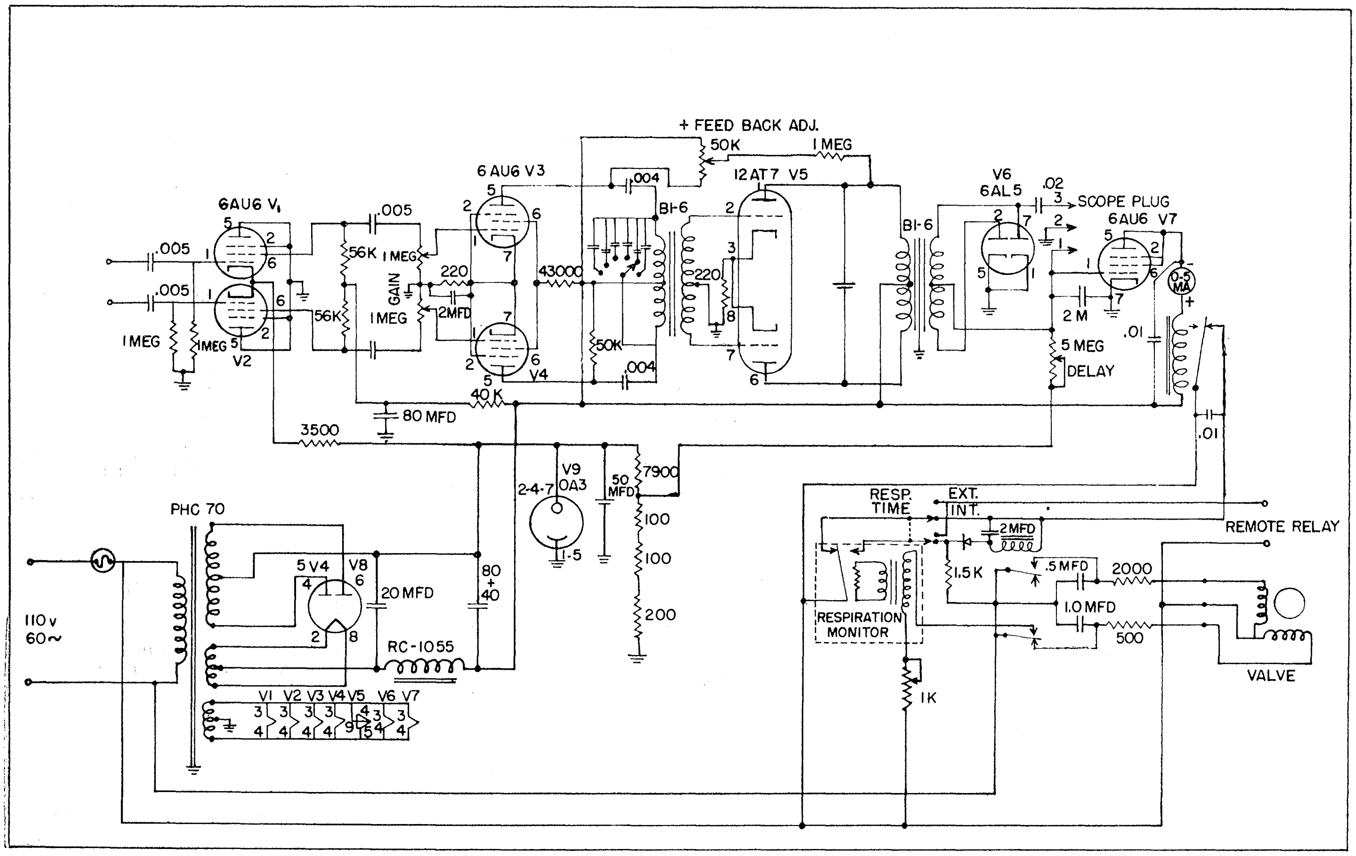

Fig. 1. Electronic circuits used to control the respirator.

input amplifier is quite effective in reducing artifacts (such as electrocardiograph potentials, stray 60-cycle-per-second, and other noise frequencies) to a value that is easily tolerated. The gain of the amplifier is adjusted to the optimum point by the attenuator between the first and second stages. By tuning the output of the second stage, the discrimination against interference may be further increased.

The filtered signal voltage is further amplified by the third stage, which feeds into an integrator circuit. The integrator produces a control voltage which is roughly proportional to the action potentials of the muscle in use. The integrated signal voltage is then further amplified by a d-c amplifier stage which in turn controls the action of the normal operational relay.

In the amplifier units designed for experimental use, a relay which operates a rotary solenoid valve controls the flow of air to and from the respirator. To provide an extra margin of safety, a monitor is included in the units intended for clinical use. This is designed to take over within defined limits the control of the respiratory cycle if the amplifier unit operation exceeds normal limits for the patient involved. Monitoring is accomplished by using an electrically heated wire, the thermal expansion of which is used to operate a contact-making lever. On this unit, when the normal operation relay contact closes for the inspiratory phase, a position relay which controls the solenoid valve also energizes a transformer that furnishes the heating current for the monitor expansion wire. The heating of this wire causes the lever to move away from the minimum respiration contact. During the expiratory and resting phase of the respiratory cycle, the current is shut off, and therefore the wire cools, causing the contact lever to float back in the direction of the low contact. Under normal operation the contact lever will float in the mid-scale range. In the event of muscle spasm, cessation of respiratory impulses, electronic failure, or other malfunction that might cause the equipment to remain on the inspiratory phase for an unduly long period, one of the range contacts will close, reversing the position relay and setting up an automatic respiration cycle which will continue until the patient resumes his normal efforts to breathe, or until the malfunctioning of the equipment is corrected. At this time the control of respiration automatically returns to the patient.

The basic principles involved in the design of this equipment have been carried over to the development of transistor models (*3*) which are planned for use with portable equipment and in situations (such as operating rooms) where the sparking contacts of the relays in the tube-type of equipment would be hazardous. In the experimental model a cathode-ray oscilloscope is customarily used to view the potentials used in the activation of the respirator.

Operation and Use

In the operation of the electronic respiratory control, some low frequency muscle potentials were sacrificed in order to obtain the smaller high-frequency components that are in a more desirable signal to noise ratio. The muscle potentials used exceed those of the artifacts in this mid-audio-frequency range. It was found desirable to make the amplifier tunable over the range from 100 to 1000 cycles per second since it was observed that the most reliable obtainable frequencies varied from patient to patient, being dependent upon the distribution and involvement of the neuromuscular units under investigation. The most troublesome interference, including the electrocardiographic potentials, is eliminated by filtering out frequencies below 100 cycles per second. Experience with the apparatus has shown that only a small percentage of the available potential has been required. It has also been observed that animals appear to "learn" that the activation of the muscle being used is necessary to operate the electronic control; at least there is observed to be improvement in the process with use, in any individual experiment.

A sufficient number of experiments upon dogs have been performed to prove the efficacy of the device in allowing the animals' neurological and biochemical mechanisms to control their own respiratory needs. Through the electronic control, the animals used in the experiments made very rapid readjustments and quickly regained relatively normal blood values after the experimenter had by interference brought about for brief intervals extreme stages of hyper- and hypoventilation (*4*).

To date, experience with patients has been confined to testing the apparatus on partially paralyzed individuals who could stay out of a respirator for part of a day and who were interested in cooperating with the investigation. These patients have relied upon the electronic control for their respiration for periods of more than 24 hours at a time while under constant observation. This included long periods of normal sleep. During the time of use it was not necessary to adjust the skin electrodes or the controls of the electronic circuit.

The apparatus has been successfully used in both patients and animals to control pressure in tank and cuirass respirators, and to control pressure changes directly through the airway as in patients with masks and animals with intratracheal tubes.

It is obvious that this apparatus has other potentialities than its use with partially paralyzed patients. Already it has been used to map surviving muscles in such patients. As a laboratory aid in physiological research, it may be of advantage in studying problems dealing with neuromuscular function and pulmonary physiology. It offers promise of assistance in the control of inhalation anesthesia, particularly in operations in the open chest. It should be useful in the study of breathing patterns under a variety of conditions and in various diseases. It may offer aid to newborn and premature infants with respiratory distress.

References and Notes

1. This work was aided by a grant from the National Foundation for Infantile Paralysis.
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4. A detailed description of these experiments is in preparation.

Integrating Device for Use with Potentiometers

W. Keith Hall, Gustave Sill, Court L. Wolfe

An automatic recording potentiometer embodies a paper chart which is driven at constant speed in the *y* direction. Motion in the perpendicular *x* direction is accomplished by a potential which is usually simply related to a quantity which varies as a function of time and whose relationship to time is of interest. If, as in the case of gas-phase chromatography, the motion in the *x* direction is proportional to concentration, then the integral under the traced curve is proportional to the total amount—that is,

$$\text{Total amount} = c \int_0^\infty x \, dt$$

Similar and analogous situations exist in other types of work, such as spectroscopy, where the areas are required for quantitative analysis.

The use of gas-phase chromatography in research and in process control has been undergoing revolutionary development over the past several years (*1*). In some respects, this has altered the basic approach toward research. For example, the development of the microcatalytic technique (*2*, *3*) in this laboratory has accelerated catalytic research to such a degree that measurement of the chromatograms has become the slow step. That a similar situation exists in other laboratories is evidenced by the fact that it has become almost customary to evaluate these chromatograms by simply measuring peak heights rather than peak areas, in spite of the fact that this is an approximation and one that is particularly poor in the case of broad and assymmetrical peaks. Further, as noted earlier (*3*), one of the advantages of the chromatographic technique in the study of catalytic reactions is that the experimenter can obtain semiquantitative estimates of the results of an experiment as the experiment progresses and may be guided in his choice of the next step by the results already in hand. It was readily recognized, therefore, that even this situation could be improved if actual quantitative numbers were used to replace the visual estimates. It was on this basis that the development of the instrument described in this article was undertaken. Specifications for an integrating mechanism were drawn as follows:

1) The device was to operate in conjunction with the automatic recording potentiometer available to us (Leeds and Northrup Speedomax, 5-millivolt scale).

2) It should provide for the individual integration of each peak appearing on the chromatogram as it is drawn.

3) It should read out in digital form, totalizing to at least 99,999, to be stamped on a separate tape or else on the Speedomax chart adjacent to the integrated curve.

4) It should be reproducible to better than 1 percent.

5) It should provide for automatic clearing of the stored number after printing so that the integration of the next peak or following peaks will not be cumulative.

6) The pulse output rate at full-scale deflection on the potentiometer chart must exceed 1000 counts per minute to insure a sufficient number of significant figures per unit area. This condition amounts to asking that the device be capable of producing as many significant figures as are obtainable with a hand planimeter and with an accuracy as great as that of the average of several such determinations.

7) The device should be sufficiently intelligent to be able to distinguish between meaningful data and base line noise.

To the best of our knowledge, no commercial instrument presently available fulfills all the requirements listed. It was found, however, that an instrument satisfying these requirements could be made from commercially available basic components—namely, a ball and disk integrator supplied by the Librascope

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