NASA TECH BRIEF
Ames Research Center

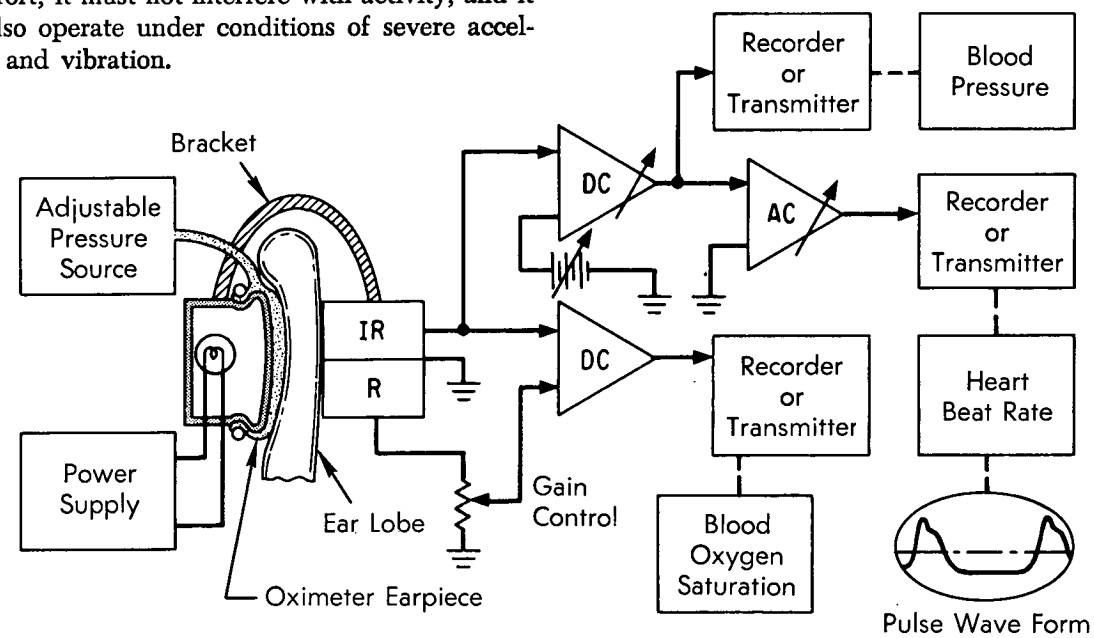
Ear Oximeter-Transducer Monitors Four Physiological Responses

The problem:

To provide a device that continuously monitors blood oxygen saturation, blood pressure, pulse rate, and the pulse-pressure curve of subjects during conditions of high stress in simulated space flight. The device must be small enough to be worn without discomfort; it must not interfere with activity, and it must also operate under conditions of severe acceleration and vibration.

How it's done:

An ear oximeter of conventional design is used to determine the oxygen content of the blood from measurements of the amount of light absorbed by the blood supply in the upper part of the ear; signals provided by the oximeter are processed to obtain other measurements. As indicated in the diagram, a lamp illuminates the ear, and the light transmitted through the ear falls on two photcells, one having a peaked sensitivity at 790 nm (IR), and the other (R) peaked at 640 nm. Light absorption by the blood at



The solution:

Utilize a conventional ear oximeter as a transducer; a continuous record of the *in vivo* blood pressure, pulse rate, and pulse-pressure curve can be obtained from calibrations of the detector output.

(continued overleaf)

790 nm is due essentially to the presence of hemoglobin, regardless of whether it is oxidized or reduced; on the other hand, absorption at 640 nm is due to oxygenated hemoglobin. Thus, the output from two DC amplifiers fed to a recorder or transmitter gives continuous indication of oxygen content.

The lamp source of the oximeter heats the ear to the extent that arterioles dilate greatly; as a result, the blood flow through the ear becomes so rapid that very little deoxygenation occurs in the capillaries. Consequently, the oxygen-saturation level of arterial blood is measured, which in most instances is more important than measurement of the oxygen saturation in the venous blood. For initial calibration, a pressure capsule acts as a cuff and presses on the ear for 15 seconds at a maximum applied cuff pressure of 250 mm so that the blood flow in arteries or veins is stopped; in this way the instrument "zero" for oxygen concentration can be obtained.

The light falling on each photocell is, of course, transformed into a DC voltage that is proportional to the intensity of illumination transmitted by the ear. After amplification, the voltage signal (the blood saturation signal) from the infrared cell sensitive to 790 nm can be measured directly by a recorder or transmitter; more importantly, however, its value varies inversely with blood volume, which in turn varies directly with blood pressure. The blood saturation signal is a DC voltage that is at a minimum when the blood pressure is at a maximum; this corresponds to the systolic pressure when no ear cuff pressure is applied to the ear tissue. Conversely, the DC signal is at a maximum corresponding to diastolic pressure. When a plot of the blood pressure signal is examined on a graph or on an oscilloscope, the difference between the systolic and diastolic pressure may be obtained directly.

The light falling on the infrared cell constantly fluctuates in intensity as blood pressure-pulses from the heart pass through the ear. Consequently, the output of the IR cell has an AC signal with a peak-to-peak amplitude which is proportional to the difference between the systolic and the diastolic pressure. The AC signal is conveniently amplified by the AC amplifier indicated in the diagram (with variable gain) for recording or further processing.

The apparatus is calibrated by adjusting the gains of the variable-gain DC amplifier, the variable-gain AC amplifier, and the adjustable voltage source bias as follows: The pressure capsule is pressurized to about 200 mm of Hg ($\approx$27 kN/m^2), sufficiently high to cut off all circulation through the ear tissue so that no blood flows under the earcuff and there is no absorption of light due to blood.

The earcuff pressure is then allowed to decrease slowly; as it becomes equal to systolic pressure, some circulation commences as noted by a decrease in the blood-pressure signal and the appearance of some pulse-pressure wave forms. The earcuff pressure is noted (since it is the systolic pressure of the subject) and at the same time a pressure-pulse signal is obtained.

As the earcuff pressure continues to decrease, the blood-pressure signal decreases (indicating absorption of light due to flow of blood) and the amplitude of the pressure-pulse signal continues to increase, showing that more and more flow due to the heart's pressure pulse passes through the illuminated tissue. As soon as the earcuff pressure is equal to the diastolic pressure, the total amplitude of the pressure pulse is utilized to pump blood through the tissues and the amplitude becomes constant; at this point, the earcuff pressure, that is, diastolic pressure, is noted.

After the earcuff pressure has been allowed to bleed off completely, the gain of the variable-gain DC amplifier is adjusted in accordance with some convenient scale. For example, the gain may be decreased so that the blood-pressure signal becomes −1.0 volt.

The difference between the systolic and the diastolic pressure may be read from a graph in a continuous manner. Additionally, the pressure-curve signal provided on a time scale affords a ready means of determining the pulse rate.

Note:

No additional documentation is available. Specific questions, however, may be directed to:

Technology Utilization Officer
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Patent status:

This invention has been patented by NASA U.S. Patent No. 3,412,729) and royalty-free license rights will be granted for its commercial development. Inquiries about obtaining a license should be addressed to:

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